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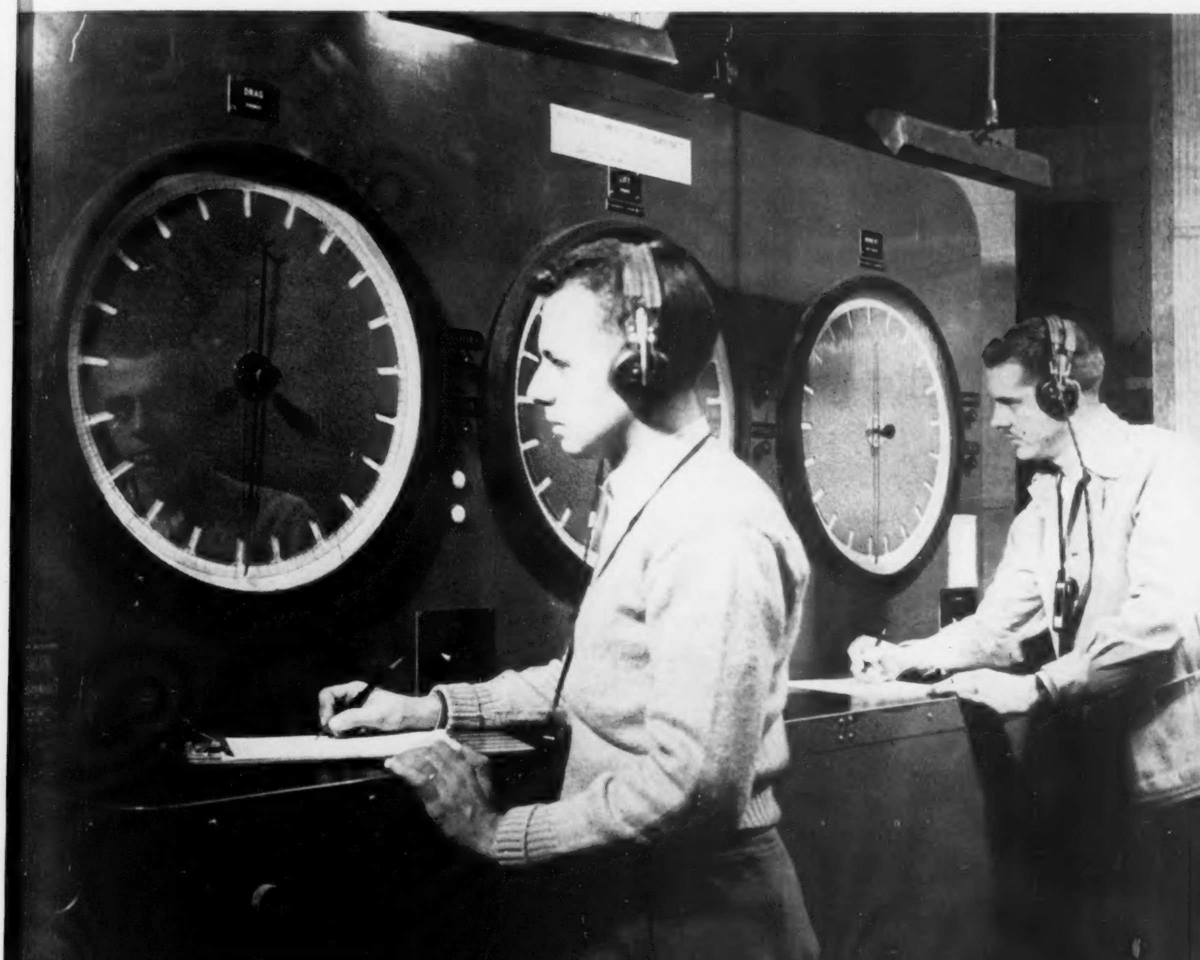

RECORDING RESULTS OF WIND-TUNNEL TESTS

See *Instrumentation for Guided Missile Development*, page 5

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THE SCIENTIFIC MONTHLY

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ON INSTRUMENTATION FOR GUIDED-MISSILE DEVELOPMENT*

By COLONEL LESLIE E. SIMON

Colonel Simon is a West Pointer of the class of 1924 and also a graduate of Massachusetts Institute of Technology (1929). He is now Director of the Army Ordnance Department's Ballistic Research Laboratories, Aberdeen, Md. He has specialized in statistical methods for quality control of ammunition, etc. He is the author of a leading textbook on statistical methods for engineering use, and his book on German Research in World War II was published in May 1947.

FEW new subjects have excited broader interest or more speculation than guided missiles. The concern of the whole Army, Navy, the Congress, and the general public is welcomed by the technical services responsible for the research and design of weapons, because popular interest is a stimulus to research and development work, assures financial support, and favors a swift and successful program of weapons to keep our country strong.

However, unwise technical speculation can lead to real disaster, just as unwise financial speculation led to the crash of 1929 and the subsequent depression. The technical services should not discourage popular interest in their work; but scientific realism, morality, and sound business procedure require that sufficient information be given on the present, only moderately advanced, state of guided objects to prevent enthusiastic expectations that are inconsistent with the present state of scientific knowledge and to prevent precipitous anticipation of swiftness of development not supported by previous experience. In like manner the public should be given sufficient engineering information to enable it to appreciate and understand the ambitious plans for many large supersonic wind tunnels.

Much could be said about the basic research, technical research, design, development, and manufacture of guided missiles but the single, concrete, and restricted field of instrumentation for the development of guided missiles bears so directly on the practicality of doing a new thing and is so readily understood by all concerned, from the research scientist to the casual layman, that a straightforward discussion of this subject can do much to provide for sound orientation and to promote planning which is wise, prudent, economical, and best calculated to yield usable new things in a minimum of time and with a minimum of expense.

By way of specific illustration, let us suppose that a large aircraft company has just accepted a government contract to develop a guided missile to fly 500 miles with a 1,000-pound pay load. The managers of the company may have accepted the contract without a great deal of investigation because they were anxious to get into the new field of guided missiles and knew that others no better equipped than they were already doing so. The problem is turned over to the tech-

* In a slightly different form this article appeared under the title "Instrumentation for Guided Missiles" in *Logistics*, a journal of the Army Ordnance Association, January 1947.

nical staff of the company, and these gentlemen immediately precipitate a crisis. They insist the company has neither the basic design data on which to proceed nor the instruments with which to do the necessary technical research for acquiring it, and that a supersonic wind tunnel is a necessary instrument for any sort of rational design.

The chances are that they will then obtain permission to visit the Ordnance Department's Ballistic Research Laboratories (BRL) at Aberdeen Proving Ground. It may seem astounding that the Ordnance tunnel, which has been running for over two years, is still, according to various representatives of aircraft companies engaged on missile work, the only supersonic tunnel in the country today in which they can get their models tested. Let us see what a supersonic wind tunnel involves in time, money, and people.

The Ordnance Department began its supersonic tunnel in 1939 in response to a suggestion from Professor Theodore von Kármán. The first step consisted of thinking and planning with the assistance of the best minds in the country as advisers. Concurrently, work was begun on a free-flight aerodynamic range in which the motion of a model can be measured accurately throughout its flight and the accompanying phenomena in the surrounding air measured at least approximately. The free-flight range is needed in connection with calibration of the supersonic tunnel and for measurements at velocities near the velocity of sound where no wind tunnel can function. It required over two years to develop the free-flight range under the able direction of one of Professor von Kármán's promising young assistants, Dr. Alexander C. Charters.

THE DESIGN OF MODELS IS A SPECIAL ART

STRENGTHS OF MATERIALS DO NOT PERMIT MERE SCALING DOWN WHEN THE STRESSES OF SUPERSONIC SPEEDS MUST BE MET. PARTS MUST BE STRENGTHENED AND BRACED, YET INTEGRITY OF SHAPE MUST BE PRESERVED.

The second step was the construction of a model tunnel, only 2.5″ x 2.5″ in working section. This tunnel was built with the assistance of the National Defense Research Committee and operated for over two years on small missiles such as caliber 0.30 and caliber 0.50 bullets, in order to obtain the operating techniques and the basic design data for the large supersonic wind tunnel. Finally, in 1943 the construction of the tunnel was begun, and useful work on the wind tunnel began in the fall of 1944.

It requires a staff of approximately 100 people to man the supersonic tunnel on a three-shift basis. The cost was $2,000,000. It worked from the beginning. Its successful functioning from the very opening was due to the excellence of scientific guidance available to the Ballistic Research Laboratories, which had not only an outstanding scientific staff but also a civilian scientific advisory committee composed of the leaders of the fields of science supporting ballistics. This committee has guided the Laboratories since their inception, both in policy and in problems of major difficulty.

The fundamental purpose of a wind tunnel is to obtain measurements of the air forces that will be valid for missiles in free flight. Therefore, if it had not already become apparent before the construction of the tunnel, it would certainly have become apparent immediately afterwards that it is a prime necessity to have along with the wind tunnel some method of measuring the forces on objects in free flight so that wind-tunnel techniques to reproduce free-flight results may be developed. Since the Ordnance Department's Ballistic Research Laboratories had developed a free-flight aerodynamic range before the construction of a supersonic wind tunnel, the facilities were already at hand for accurate comparison of wind-tunnel and free-flight data. The free-flight range was built partly in anticipation of the tunnel, but primarily because of the contribution it alone could make to the satisfaction of the Ordnance Department's interest in bullets and shell, which have been fired at supersonic velocities for decades. It is only recently that agencies other than the Army or Navy have had any great practical interest in supersonic phenomena.

Another important function of the free-flight aerodynamic range should not be overlooked. That is to supplement the wind tunnel in what may be called the wind tunnel's *blind spot*, the range of velocities near the velocity of sound. At velocities slightly less than sonic, the model *blocks* the flow in the working section; at velocities slightly above, the nose waves hit the side of the tunnel, are reflected, and hit the model along the body or the tail. Thus wind-tunnel measurements in this range of velocities, called the transonic, cannot reproduce free-flight conditions. Incidentally, it should be remarked that the smaller the ratio of model size to tunnel size, the more closely the velocity of sound may be approached from above or below.

Let us now consider the first facts learned by the hypothetical company's engineers from their visit to the BRL. First, they need not only a supersonic wind tunnel but a supersonic laboratory consisting of a tunnel, free-flight range, and other accessories. Second, the cost is very high, and the time required for a successful development of such facilities is long (two to four years). Third, the most important thing in a ballistic laboratory is a considerable number of really good scientific brains, and these are extremely scarce. The conclusion is rather obvious. The engineers decide that it is best and most economical to have their exterior ballistic and aerodynamic work done for them by the government agency which by dint of long effort has acquired competence in these fields.

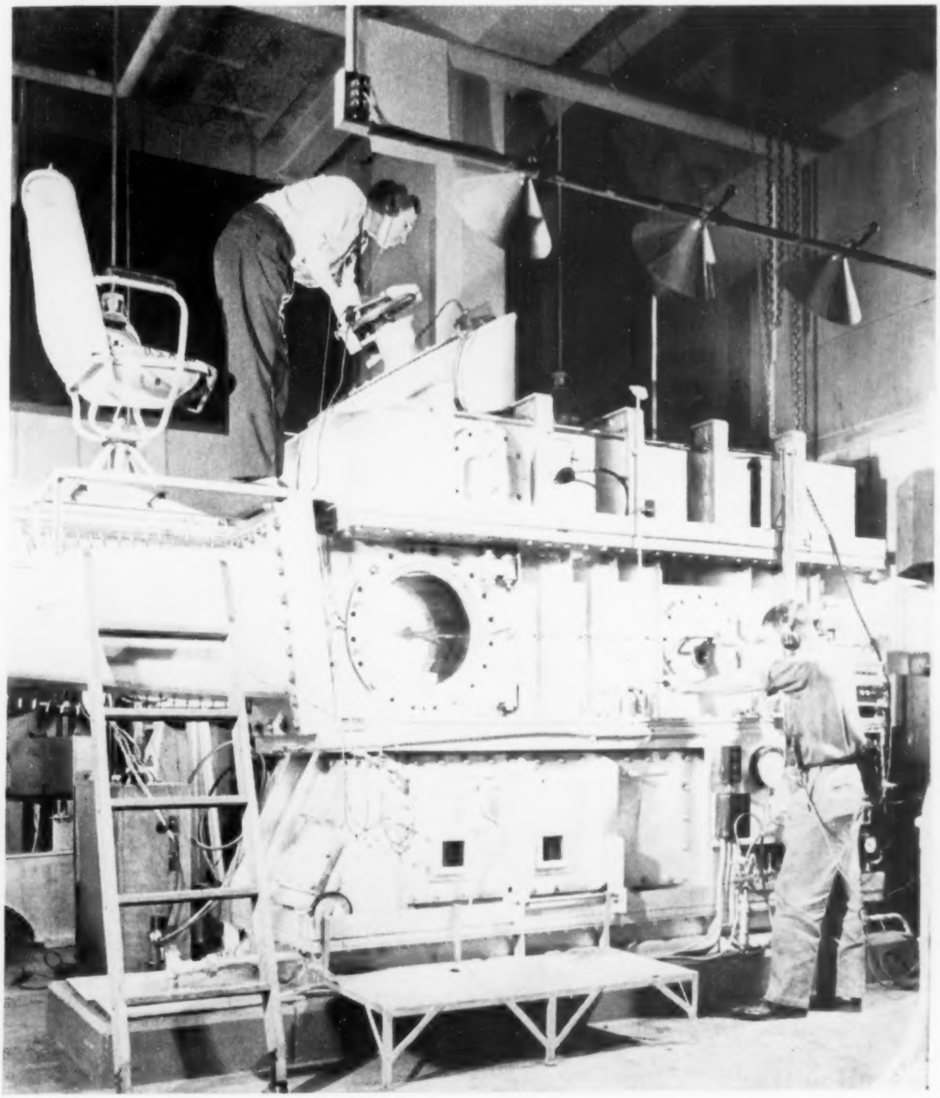
The Ordnance Department began work on supersonic guided missiles over two years before V-E Day, well ahead of any other government agency and before the German

V weapons were fired at England; not as a stopgap development, but as a carefully planned long-range research and development program. After the wind-tunnel tests of the models, the first prototypes were fired with emphasis on the test of body shape, the next series to test fins and stabilizers only; the third series to test motors and fuels; and the series now being fired is the first prototype expected to be reflected in a useful missile. The effectiveness of all trials depends upon good field measurements of aerodynamic characteristics. Instrumentation for full-scale measurements in the field was approached with the same careful attention to pertinent detail as that for measurements on models in the supersonic laboratory. For short-range measurements optical methods suffice; for some types of measurements optical methods at present appear necessary; but for long-range measurements and measurements through clouds only those which depend on invisible electromagnetic radiation have been successful.

Electronic measurements currently used consist in general of: ordinary radar; radar plotting boards; pulse radar, in which short streams of pulses are directed toward the missile, sent back by the missile, and the position calculated from the measured time interval between sending and receiving the pulse; and radio Doppler, in which continuous signals are used and the position, velocity, and acceleration calculated from the change in frequency caused by the movement of the missile. Electronics is such a rapidly changing field that one sometimes hears the remark that anything written on the subject is obsolete before the ink gets dry. Models of missiles also change rapidly; each

MODEL-MAKING REQUIRES GREAT SKILL

TOLERANCES MUST BE SCALED DOWN IN PROPORTION TO MODEL SIZE. MACHINING MUST BE METICULOUS.



A MODEL BEING TESTED IN A WIND TUNNEL

THE POSITION OF THE MODEL WITH RESPECT TO THE ONRUSHING AIR IS ADJUSTED BY MEANS OF A MECHANICAL LINKAGE WHICH IS BEING OPERATED BY THE MAN ON THE TOP OF THE WIND TUNNEL.

one goes farther or faster. Thus, field measurements of guided missiles is one of the most rapidly changing of technical fields. Over three years of experience by the Ballistic Research Laboratories indicates that the expected life of a new instrument is about three shoots. By the time an instrument has been used three times, it is likely that either the Laboratories have devised a more effective method of measurement or the missile has been so much improved that the method is no longer applicable. The Signal Corps, and especially the Camp Evans Laboratory, have been unstinting in their aid in the electronic measurements.

Furthermore, the instrumentation can be

AN ARRAY OF CENTRAL CONTROL SWITCHES

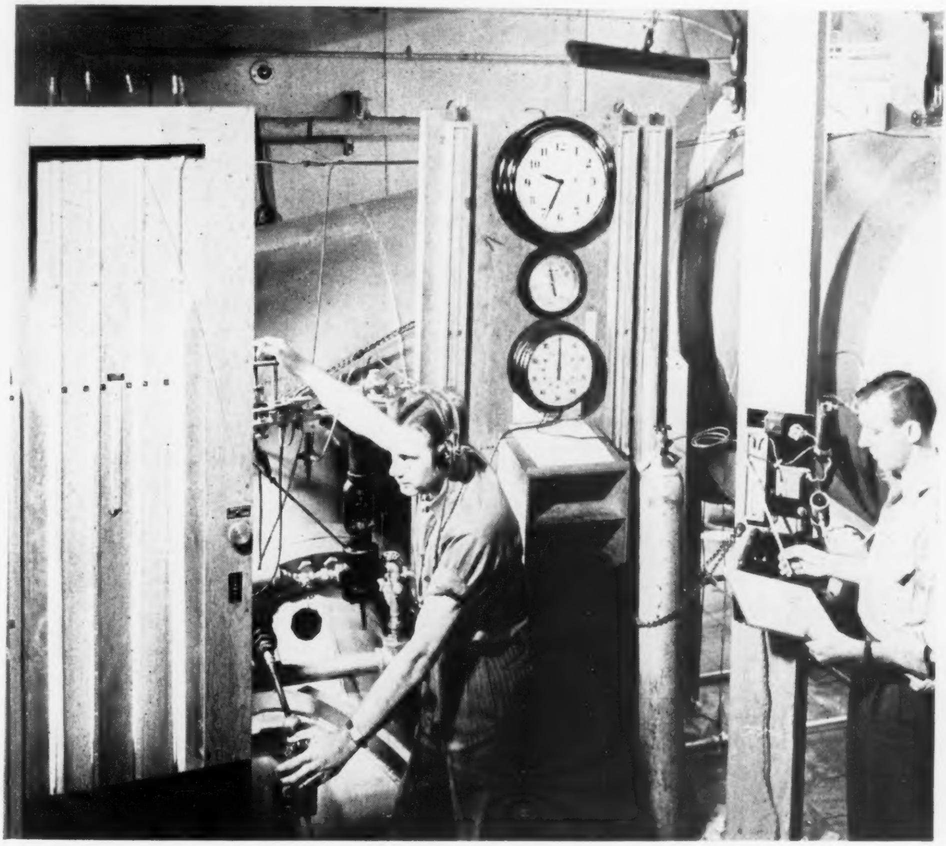
THESE ARE REQUIRED TO CONTROL THE COMPRESSORS AND MANY VALVES, THEREBY PROVIDING A VARIETY OF AIR SPEEDS, EACH AT A VARIETY OF DENSITIES. THUS, MODELS CAN BE THOROUGHLY EVALUATED.

supported only by research personnel, not by ordinary operators, nor even by routine engineers. It is only by having a research staff operating instruments in the field, coming back to the laboratory to make new instruments, and going back to the field to try the new instruments that the pace can be met. Men of vision, energy, foresight, and of great native intelligence and originality must be used. Even under these conditions it takes as many as two and one-half men in the laboratory to support one man in the field.

Ordnance has rarely missed a field measurement, because it has competent men who are working on electronic and optical instrumentation. They can devote their full talents to these highly technical problems. Until field measurements of guided objects become stabilized (similar to measurements

of gun-fired projectiles), success is dependent upon employing men who can regard today's measurement with disdain but who have a consuming interest in tomorrow's measurement. The satisfaction of scientific curiosity about tomorrow's measurement, of course, leads to the ability to regard it as simple when tomorrow arrives. The support of ballistic measurements at White Sands Proving Ground alone is costing over a million dollars a year exclusive of communications and other proving-ground costs.

The motion of the missile during certain portions of the trajectory—especially during the beginning of its trajectory—must be known with extreme accuracy. These measurements require the development of highly specialized cameras. The cameras used for this purpose run at extremely high speeds with very short exposures, use film as wide as five inches, must record the position and time of the missile, and all cameras in a system must be carefully synchronized. While the requirements of accuracy of timing for optical measurements are not so extreme as those for radio Doppler measurements where frequency is measured to one part in ten million, nevertheless, time in optical measurements must be measured to one part in one hundred thousand. For measuring angle of attack and yaw of the missile along its flight, a camera is used



FLOW CONTROL REGULATOR

AIR IS LET INTO THE SYSTEM FROM THE SUPPLY SPHERE UNTIL THE DESIRED PRESSURE IS REACHED. A CONSTANT PRESSURE IS THEN MAINTAINED TO WITHIN PLUS OR MINUS 0.5 MM. OF MERCURY.

which will yield a picture of a German V-2 at 20 miles such that the missile occupies one-half a 35-mm. moving-picture frame. These optical measurements require also a highly specialized scientific group. Because some measurements almost always fail, and because the shooting of a prototype is an extremely expensive operation, the Ballistic Research Laboratories ordinarily employ five different kinds of electrical measurements and five different kinds of optical measurements.

Most of the field measurements, including the electrical measurements, are recorded photographically. The films must be properly developed and read by means of film viewers, precision comparators, and other instruments; but, more important still, the application of many of the most advanced mathematical techniques is necessary to transform the data into terms suitable for engineerng application. Many of the computations are so long and involved that great expense and loss of time would occur if reliance had to be placed upon human computers. In addition to a differential analyzer (popularly known as the mechanical brain) and the ENIAC, the BRL also has two new and powerful computing devices in the relay computers of the International Business Machine Corporation and the Bell Telephone Relay Computer designed by Dr. Stibitz and built by the Bell Telephone Laboratories. These machines, in addition to ordinary IBM machines and other conventional devices, are used to reduce the expense and labor of reduction of observations as well as to solve general scientific problems of government and nongovernment agencies.

We have not mentioned perhaps the most important thing of all. If the missile is to damage its target except by direct impact, it must have a warhead, perhaps atomic, but usually a warhead containing a high explosive. Beginning well before World War II, the Ballistic Research Laboratories began actively to develop facilities for the measurement of blast, fragment velocities, etc., and to acquire a competent staff to analyze such data and to conduct the necessary basic and technical research to provide a sound basis for design of specific types of warheads as requested. Our hypothetical missile designers, having had no previous experience with warheads, blast, and fragmentation will naturally ask the Ballistic Research Laboratories to assist in this highly important job and to test and criticize models and actual warheads as they are developed. So far as I know, the Laboratories are the only agency in the United States prepared to furnish such basic design data and to make such tests at the present time.

Thus the airplane company's representatives may well see that their competence in aerodynamic engineering is but a minor auxiliary to the task at hand, even less important than ballistics, and that the instrumentation for the development of guided missiles involves the following facilities, together with competent staffs:

1. Supersonic wind tunnel.
2. Free-flight aerodynamic range.
3. Powerful computing devices.
4. Facilities for the measurement of the aerodynamic characteristics of full-scale missiles in free flight.
5. Facilities for the study, development, and testing of warheads.

The facts learned by the representatives of the hypothetical airplane company are not nearly so important as the facts that can be deduced from this discussion with regard to the welfare of our country. It is well known to the technical services and has been stated in part in the press that plans are being formulated for the construction of a score or more supersonic wind tunnels, at stupendous cost, with single tunnels requiring as much as 500,000 h.p. and with velocities as high as ten times the velocity of sound. Certainly public interest requires that these plans be examined openly and critically.

The Ordnance Department's Ballistic Research Laboratories and about four supersonic tunnels that are operating or being prepared to operate employ almost all the qualified personnel that can be squeezed out of the colleges today without doing definite harm to the education of future scientists. Furthermore, the associated personnel on design, instrumentation, computation of data, and interpretation of results that would accompany the operation of a large number of supersonic facilities would exceed by severalfold the number required for the wind tunnels. Hence, the plans are feasible only as extremely long-range plans to be met, perhaps, by the students of students now in college.

There is no evidence of an immediate need for a considerable number of very large supersonic wind tunnels. The single institution of the Ordnance Department is today handling the vast majority of the country's work on Army, Navy, and Air Forces projects. I do not mean that no additional tunnels are needed. The Aberdeen tunnel is overtaxed; and, if there were more supersonic wind tunnels, there would be more testing. The question I raise is not concerned with some increase in the number of small tunnels but with the number of very large tunnels.

If anything like the present scale of appropriations for guided-missile development continues, there is no doubt that additional wind-tunnel facilities are urgently needed. However, construction of a number of supersonic wind tunnels is now well advanced. These tunnels will be comparable in size, cost, and power requirements to the Aberdeen tunnel. A good case may also be made for the construction of a small number of tunnels of greater size than the Aberdeen tunnel. Its working section, approximately 15″ x 13″, cannot handle models much greater than two inches in diameter.

THE SCHLIEREN CAMERA

IT TAKES PICTURES OF THE DENSITY GRADIENTS ABOUT THE MODEL, NOT VISIBLE TO THE UNAIDED EYE.

There are difficulties in making accurate models this small. Moreover, the successful operation of the Aberdeen tunnel gives a reasonable expectation that a somewhat larger tunnel with a working section 4′ x 4′ could be successfully operated. Such a tunnel would cost about $20,000,000 if it is to attain air speeds up to four times sound speed. But to jump now to tunnels with working sections 18′ x 18′ or more and costing 100 to 200 million dollars each is something else. Moreover, to operate such a tunnel on a one-shift basis would cost something like $20,000,000 a year. *To justify such expenditures one would have to show that indispensable data could be got from these enormous tunnels that could not be got from smaller tunnels or from free-flight ranges.* I believe that not until much more experience has been gained from the small tunnels existing and being built and until extensive comparisons have been made of wind-tunnel data with data obtained from small-scale and full free-flight ranges would one be justified in asserting that the data from the $100,000,000 tunnels are really indispensable. In this, as in other allied scientific fields, prudence is the best policy.

The arguments presented to justify these huge expenditures should be examined. So far as I have heard there are two: (1) the existence of scale effects and (2) the inability of wind tunnels to reproduce free-flight conditions near the velocity of sound.

An appreciable fraction of the total resistance on a body moving at supersonic speeds is due to skin friction, and this skin friction depends upon scale. By this I mean that the skin friction force does not vary exactly as the area. Although the existence of scale effects at supersonic speeds has been demonstrated, the question is whether the huge supersonic tunnel is an indispensable tool for studying this effect. This effect can be studied even in tunnels like the Aberdeen tunnel, and if this proves insufficient one can measure the forces in full-scale free-flight ranges such as at White Sands with much less expense than is involved in making the proposed huge wind tunnels.

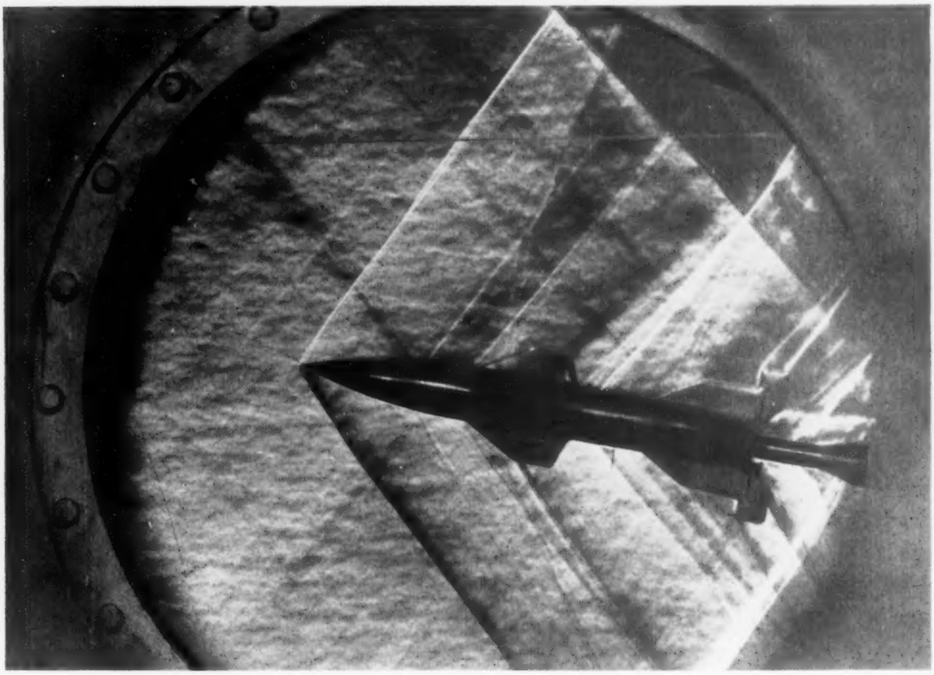
The blind spot of wind tunnels near the velocity of sound has already been mentioned. It is apparent that with a given sized model, the larger the tunnel, the smaller the blind spot would be. However, the air forces in the transonic region can be measured in free-flight ranges. Why make a tunnel with a 20′ x 20′ working section to do it until the free-flight measurements have been shown to be inadequate?

I do not pretend to be an aerodynamicist or an expert on wind tunnels, although I have seen a good deal of the Aberdeen tunnel and of various German wind tunnels. Therefore, I do not ask anyone to follow my advice on this matter. I suggest, however, that in formulating plans for the proposed wind tunnels it would be well to follow the example set by the Ordnance Department in the construction of its supersonic wind tunnels, that is, to get the advice of a competent and disinterested agency. Before any definite plans for the construction of the Aberdeen tunnel were made, the National Academy of Sciences was asked to give its opinion as to whether construction of a high-speed supersonic wind tunnel with velocities going up to four times sound velocity would be justified. It was not until a committee of the National Research Council which the National Academy of Sciences appointed to study this question had reported in the affirmative that design studies for the model tunnel to be used as a basis for the Aberdeen tunnel were started. I should like to suggest that the government agencies interested in the acquisition of these huge wind tunnels should likewise get the advice of a competent and disinterested agency before active planning is undertaken.

The ultimate responsibility for guided missiles rests with the Air Forces, but it appears to be the intent of all concerned to make wise use of all available research and development facilities wherever located.

Hence, it does not appear amiss to cite an Ordnance example of realistic planning that exhibits boldness, vision, and foresight without yielding to irresponsible and extravagant impulse. Ordnance has a single responsibility, namely, weapons to make the country strong. In pursuance of this single purpose, it foresaw before any other institution the need for high-speed supersonic tunnels. It followed a modest, logical, and scientific plan. It began by (1) getting the most competent advice, (2) building an aerodynamic range, (3) building and operating a model tunnel, and (4) building a large tunnel which worked successfully at its inception.

While building this tunnel (which goes only to four and one-half times the velocity of sound) the BRL foresaw even then the need for a tunnel that would go to ten times the velocity of sound. In the construction of the tunnel building over two years ago, connections and facilities were built in to provide for a free-flight range, or aerodynamic range, to go to this velocity. This free-flight range is now under construction and so also is a model tunnel to obtain ten times the velocity of sound. The careful construction of a model (the exercise on a small scale of the scientific method of hypothesis, experiment, and test of hypothesis) is the swiftest way to the construction of a large tunnel. The Ordnance Department has not yet planned a larger Mach 10 wind tunnel because insufficient basic design data are available for its proper and logical planning.



SCHLIEREN PHOTOGRAPH OF A MODEL OF A GUIDED MISSILE

THE NOSE AND FIN SHOCK WAVES ARE CLEARLY VISIBLE. REGIONS OF RAREFACTION ARE DARKER.

The most important feature of research and development, which is also the most important argument for caution in expansion of the mere tools of research and development, has not been discussed, however. The need today is for earnest, continued, and painstaking research—not mere multiplicity

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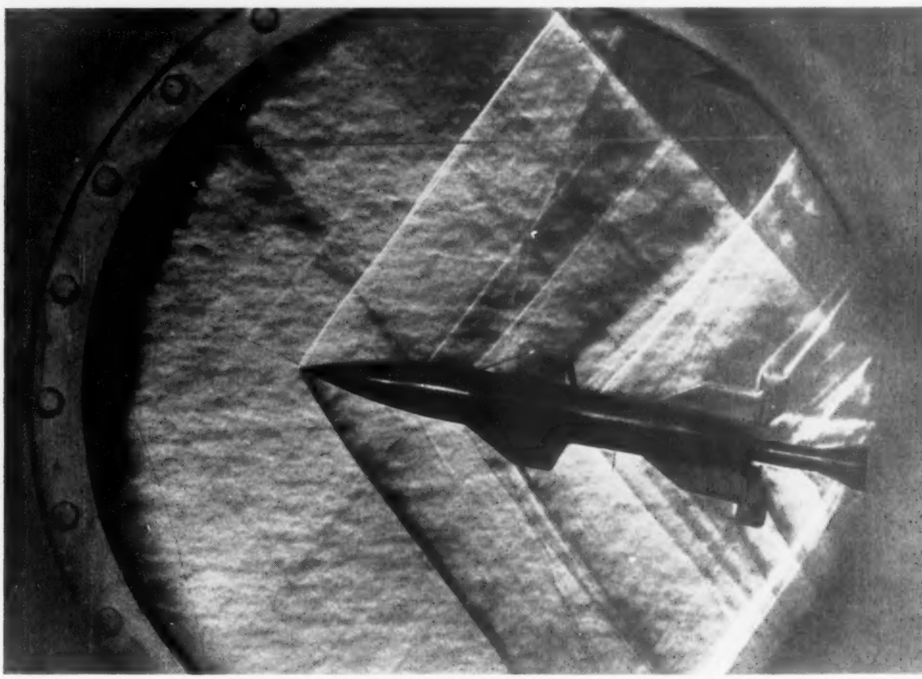

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or magnitude of experimental facilities. The research must be motivated by a genuine love for research and must be continuing and single-purpose in character, so that the research institution becomes a repository of scientific lore on the subject of its research. Short-term contracts with agencies whose major field of interest is other than weapons can only supplement and never replace the research of institutions that have a long-term interest in weapons.

Concurrent with research one needs continued and long-term development, supported by the required technical research and the needed facilities. The development should not aim at producing full-fledged guided missiles ready for production in a year or two but rather should start out modestly and proceed step by step, beginning with purely experimental missiles; designers should learn by doing before starting in earnest on the design and construction of full-scale missiles.

It should be pointed out that no one has yet guided a supersonic missile in the generally accepted meaning of the term, except for a few test models of the German flak rocket Wasserfall. The German V-2 is a fairly near approach to a guided supersonic missile; and, since its guidance functioned only during burning, it was really guided only in the sense that an artillery shell is aimed. It is reasonable to expect that long-range rockets and guided missiles will largely replace the tactical and long-range bombing planes, the long-range gun, and the large antiaircraft gun. As such they will, perhaps in five to ten years, be vital to the nation's defense. So-called push-button warfare is only a remote possibility in the light of the present state of science.

The broad public interest in the research and development of guided missiles assures gratifying support at least for the present, but two current dangers must be recognized. Ill-considered plans for huge supersonic tunnels at excessively high speeds not only present a danger of monetary extravagance, but threaten to dissipate our resources of scientific personnel. They indicate an abdication of scientific imagination and a resort to the "brute-force" method of solving engineering problems. But, worse still, irresponsible and unwise management responding more to wishful thinking than to scientific guidance can lead the country to a state of confusion which can readily result in delaying for years the development of the guided missiles about which the current enthusiasm and support have been aroused.

THE STEAMER *ALBATROSS*

By JOEL W. HEDGPETH

Mr. Hedgpeth (M.A., California, 1940) is a marine biologist and an unusually entertaining writer. He has contributed several articles and book reviews to the SM. *He may be addressed at the Texas Game, Fish and Oyster Commission, Rockport.*

WHEN it was announced last summer (*Science*, **104,** 13, 1946) that the Oceanographical Institute in Gothenburg was planning a world-wide oceanographic cruise with a ship named "Albatross," many American scientists with long memories may have wondered if the old *Albatross* had been found again. To younger students of marine biology, the name "Albatross" was only vaguely familiar or meant nothing at all. The announcement reminded a few, who have been particularly interested in the *Albatross* and in research ships in general, that the old *Albatross*, after 40 years of honorable service to science, disappeared 20 years ago and has not been heard of since.

This mysterious end of a famous research vessel is particularly strange when it is remembered that the *Albatross* was the first vessel built specifically for oceanographical research and that its name was virtually synonymous with that of one of our greatest students of marine biology, Alexander Agassiz. To be sure, that most famous of research vessels, the *Challenger*, came to an ignominious end—she was cut down to serve as a coal barge in her declining years. But the *Albatross*, sold out of service to a private company, was tied up in a libel suit and forgotten. The Swedish *Albatross* is a different ship altogether. Inasmuch as the Swedish research vessel is owned by a private shipping concern, which uses it as a training vessel, and has been lent to the Oceanographical Institute of Gothenburg for the cruise, the name cannot be changed just to avoid confusion. The name of the expedition will be Svenska Djuphavsexpeditionen med *Albatross*. As the Director of the Institute, Dr. Hans Pettersson, has informed me (by letter), this official title of the expedition, together with "the time interval of more than forty years between the original *Albatross* cruises and our own will probably prevent any mistake between the two ships,

ONE OF THE BEST PHOTOGRAPHS OF THE *ALBATROSS*

Courtesy Dr. Hans Pettersson
THE SWEDISH *ALBATROSS*

except possibly from perfectly ignorant people who are welcome to their confusion."

The original *Albatross* was built for the U. S. Fish Commission in 1882 by Pusey and Jones, of Wilmington, Del. The ship was originally an iron, twin-screw vessel with a brigantine rig, carrying sail to a fore-topgallant. She was 234 feet long over all, with a beam of 27 feet 6 inches and a displacement of 1,074 tons. She was built according to designs prepared under the supervision of Dr. Spencer Fullerton Baird, first U. S. Commissioner of Fisheries, and Captain Z. L. Tanner, who had been commander of the *Fish Hawk*, a coastal research vessel, prior to the construction of the *Albatross*. The *Albatross* was provided with laboratories, darkroom, storage rooms for specimens, and an elaborate dredging apparatus with a capacity of several thousand fathoms of cable. In addition to being the first vessel designed especially for deep-sea research, the *Albatross* was the first United States Government vessel to be completely equipped with electric lighting. This venturous innovation was for the benefit of the scientists, to enable them to sort dredge hauls after dark. The ship was also provided, however, with old-fashioned oil lamps as a safety factor. The *Albatross* carried a complement of 80 officers and men, drawn from naval personnel. The scientific staff, usually headed by the ship's resident naturalist, varied according to circumstances.

The building of the *Albatross* was not the first venture of the United States in marine research but rather the culmination of a long period of investigation that dated back to Benjamin Franklin's first studies of the Gulf Stream in 1770. Under Franklin's collateral descendant, B. F. Bache, the U. S. Coast Survey began to study the problems of the Gulf Stream in 1846. This investigation led to the expeditions of the *Blake* in the Gulf of Mexico and the Caribbean in 1877 and 1878. These expeditions were directed by Alexander Agassiz, son of the famous Louis, of Harvard. The investigations of the Fish Commission began in 1871, and its study of the decline of the New England fisheries soon made apparent the need for a deep-sea research vessel. To fill this need, the *Albatross* was built, at an initial cost of $148,000, and she put to sea on her first cruise on April 26, 1883, after a series of test runs. Her first investigations were between Cape Hatteras and the Grand Banks and concerned the movements of the menhaden, mackerel, and bluefin, as well as other commercially important fishes. The investigations lasted for five years, under the general supervision of Commissioner Baird, although the collections were actually studied by Professor A. E. Verrill, of Yale, and his assistants. Almost from the beginning, however, the *Albatross* brought up so much material in the dredge hauls that some of the collections remain unclassified to this day.

After completing her work in the Northern Atlantic and making several cruises to the Caribbean, the *Albatross* was transferred to the Pacific. She left Norfolk, Va., for San Francisco on November 21, 1887, and arrived in San Francisco on May 11, 1888,

after circumnavigating South America by way of the Straits of Magellan. The original plan to occupy an extensive series of dredging stations on this voyage had to be abandoned because of a cholera epidemic in Chile, which prevented the *Albatross* from putting into port for coal along the western coast of South America.

Soon after arriving in San Francisco, the *Albatross* was dispatched to Alaska, where she became a familiar sight. She was used for salmon and halibut investigations, the Pribilof Islands fur-seal patrol, ethnological expeditions, and hydrographic surveys of the Bering Sea. During the 20 years following the arrival of the *Albatross* in San Francisco, she made a voyage to Alaskan waters almost every year.

It was not until 1891 that Alexander Agassiz made his first voyage on the *Albatross*. At that time a wealthy mining operator, Agassiz made an agreement with the Bureau of Fisheries under which he paid the ship's coal bills, determined the itinerary, and was allowed to select the choicest part of the collections for the Museum of Comparative Zoology. His first cruise was to the waters off Central America and around the Galapagos Islands. This was the first voyage made by the *Albatross* in behalf of "pure" science, for all her previous expeditions had some practical object in view, such as fisheries research, hydrographic survey, or patrol duty. The region westward of the Isthmus of Panama was chosen by Agassiz because of his interest in the problem of the relation between the marine faunas of the Gulf of Mexico and those of the Pacific, and because this region had been missed by the *Challenger* on her pioneer voyage.

Agassiz' study of the relation between the faunas of the Atlantic and Pacific sides of the Isthmus was never completed, but the results of this first cruise were interesting enough to encourage further expeditions. In 1899 he financed a second expedition, this one to the South Seas and Japan by way of

ALEXANDER AGASSIZ

HE DIRECTED CERTAIN *Albatross* EXPEDITIONS.

the Marquesas, Society, and Marshall Islands. It was during this cruise that Agassiz made many important observations of coral reefs, the ship was given a large billy goat by a native chief in the Marquesas, and the deepest successful dredge haul on record was made. This last event occurred at latitude 21° 18′ S., longitude 173° 31′ W., on November 27, 1899, when some fragments of a sponge were hauled up from a depth of 4,173 fathoms, almost four miles below the surface.

On her third expedition under Agassiz, the *Albatross* cruised the eastern tropical Pacific between the coast of Chile and the Paumotos during 1904 and 1905. This cruise was followed in 1906 by an expedition to Japan, during which an extensive series of dredging stations was occupied in the coastal waters off Japan. This was probably the last time, until the recent end of the war in the Far East, that a foreign vessel was permitted to operate so extensively in the Mikado's home waters.

As the ship was returning from this cruise, the captain of the *Albatross*, Lieutenant Commander L. M. Garrett, was lost overboard in mid-ocean. This tragedy occurred on November 21, 1906, while the ship was under full sail. The captain was asleep in a deck chair and was apparently thrown overboard by a sudden lurch of the vessel.

The longest cruise undertaken by the *Albatross* was the investigation of the fisheries resources of the Philippine Islands, carried out in 1907–10. This cruise was under the direction of Dr. Hugh M. Smith, later Commissioner of Fisheries.

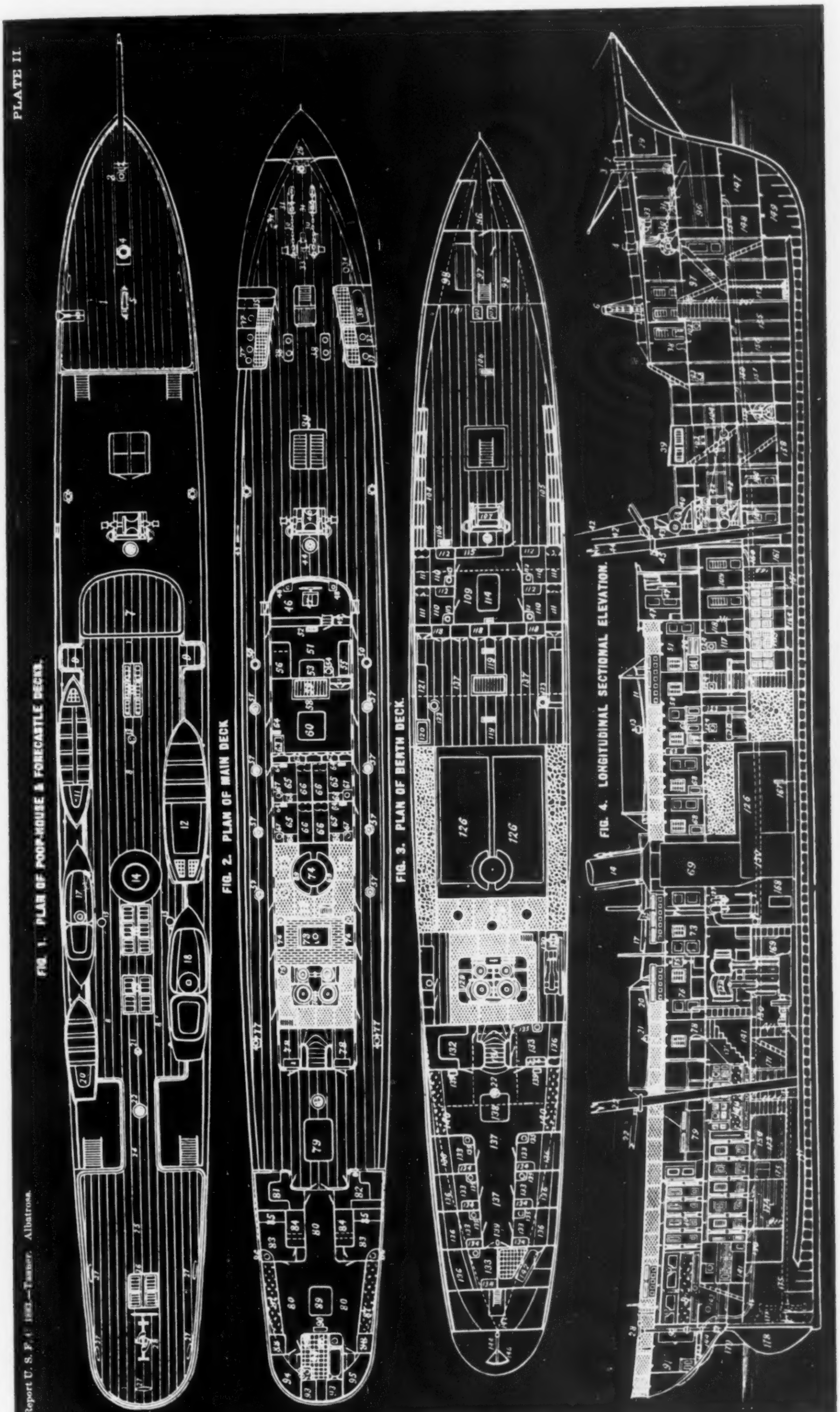
When the *Albatross* returned from the Philippines, she had been in continuous service for 28 years and was beginning to show her age. After a short cruise to the Gulf of California in 1911, the ship was found to be unseaworthy and was confined to San Francisco Bay until 1914. During this time she was engaged in a hydrographical survey of San Francisco Bay and was then laid up for overhauling and refitting. Among other things, the rig was changed from that of a brigantine to a schooner by removal of the spars on the foremast, and a radio shack was added. Despite these repairs, the *Albatross* became increasingly inefficient and was frequently laid up for repairs between short expeditions. During the war years of 1917–19 the *Albatross* was placed in naval service and was used on antisubmarine patrol in the Caribbean. After being returned to the Bureau of Fisheries in 1919, she made a short cruise to Yucatan. During the last months of 1919 and the early part of 1920 she was employed on the oceanographic survey of the Gulf of Maine, under the direction of Dr. H. B. Bigelow. Her last station, a hydrographic observation, was made on May 19, 1920.

By this time the *Albatross* had become too expensive for operation by a bureau pinched for funds, and the ship was retired from service. She was formally decommissioned on October 29, 1921. Three years later the vessel was sold to Thomas Butler and Company, of Boston, for $2,276 and passed from the hands of the Bureau of Fisheries on June 24, 1924.

It was the intention of the new owners of the *Albatross* to use her as a training ship for merchant-marine cadets, and she was refitted along her old lines for this purpose. Sometime during 1928, under the management of the American Nautical Schools, Inc., the *Albatross* embarked upon her first—and last—training cruise. Evidently all was not well with the management, for the cadets deserted the ship at various European ports, and the crew sued for wages. At the request of the officers and crew, the *Albatross* was tied up in Hamburg, Germany, on October 18, 1928, to be auctioned for settlement of their wages. Of the 119 cadets who had left Boston, only 21 remained aboard when the ship reached Hamburg. Thus the long career of the *Albatross* came to an end. There seems to be no record of what happened to the ship after this dispute, but probably she was junked.

Today, when our expanding population and depletion of coastal fisheries resources is bringing demands from both scientists and commercial fishing interests for investigations of the pelagic fisheries of the great oceans, the United States does not own a single ocean-going research vessel available at all times for marine biological research [See "The Wealth of the Ocean," SM, **64,** 192, 1947]. This is a strange state of affairs for a government that led the way with the construction of the *Albatross* more than 50 years ago. The Fish and Wildlife Service does have, under charter, two ships from the Maritime Service, at present being refitted as research vessels for an investigation of the fisheries resources of the Philippines. Before the opening of hostilities, the Japanese government had dozens of research vessels working throughout the Pacific Area, and the Russians now have nine research ships in the Kara Sea alone.

It is also true that the Fish and Wildlife Service does own the *Albatross III*, a vessel



PLANS OF THE *ALBATROSS*

presented to the Service by the fishing industry of the Atlantic seaboard. (The *Albatross II*, it should be mentioned, was a castoff Navy tug used by the Bureau of Fisheries from 1926 to 1934). The *Albatross III*, a standard but slightly outmoded trawler 140 feet long, required extensive alterations to fit her out for marine research. These alterations were completed early in 1942, shortly after the beginning of the war. Then the vessel was taken over by the Navy and reconverted for fighting purposes. At the end of the war, the ship was returned to the Fish and Wildlife Service. However, it now requires extensive remodeling, and, while there were some funds for this available, it was doubtful, at the time this went to press, that funds would be made available for operation and maintenance of the vessel. Without such funds, it is useless (See "Is the 'Albatross III' to be a Phantom Ship?" *Fishing Gazette*, **64,** (3), 53, 63, 1947).

In her day, the *Albatross* was considered the best deep-sea dredger extant, and duty aboard her was almost a prerequisite for scientific advancement. It would be difficult to name an older biologist in this country who has not served in some way on the *Albatross* or gained distinction through working on the collections made by the ship. As a matter of fact, the work of the *Albatross* is not yet completed, for many of her collections still remain in museums for ambitious young workers in search of problems.

The *Albatross* was manned by naval personnel, and the dissatisfactions among the officers over the prospects of advancement while assigned to duty on her and the friction between naval personnel and the civilian staff, which arose during the Philippine cruise in particular, are valuable object lessons for future conduct in the event the present Fish and Wildlife Service should acquire a similar research vessel. Nevertheless, in spite of these difficulties, the *Albatross* holds the longest continuous record of service for a research vessel, having made more than 5,000 dredging stations and logging more miles in the service of science than a dozen other ships combined.

TECHNICAL PHOTOGRAPHIC EXHIBITION, PHOTOGRAPHIC SOCIETY OF AMERICA

For the past two years a part of the annual exhibition of the Photographic Society of America has been devoted to a section showing scientific and technical photographs. More than 200 accepted prints were hung in this section at the 1946 meeting of P.S.A. From this group, a traveling show of about 50 prints was selected and made available to technical societies, P.S.A. groups, and camera clubs.

This year the annual meeting and exhibition of the P.S.A. will be in Oklahoma City. Readers of The Scientific Monthly who wish to submit prints for the technical section should secure complete information from W. F. Swann, 343 State Street, Rochester 4, N. Y. The latest date for receiving prints is September 8, 1947.

The subject matter for the technical section may cover any phase of technical photography except pictorial photographs of technical and mechanical operations. Both black-and-white or color photographs are acceptable. There is no limit to the number of prints that may be submitted by one individual.

ANOTHER WAR CASUALTY

By WARREN D. SMITH

Professor Smith (Ph.D., Wisconsin, 1908) is head of the Department of Geology and Geography, University of Oregon. He is an authority on the geology and mineral resources of the Philippines, having served as Chief of the Division of Mines, Philippine Bureau of Science. Altogether he spent eleven years in the islands. In 1908–09 he led the first scientific expedition across Mindanao. During his first year of retirement he will be President of the Oregon Academy of Science.

LOOKING recently through a copy of *Mining and Metallurgy* (December 1946), I came across a picture of the ruins of the Bureau of Mines and the Bureau of Science in Manila. To one who spent nine years as a member of the Bureau of Science staff (1907–14 and 1920–22), this brought back vivid memories and prompted me to recount the story of this institution and something about the men who worked there. As the Bureau was in its day the leading institution for tropical research in the world and as many of its former staff members have become internationally known, it seems only proper that an attempt be made to write a fitting epitaph for it. There are doubtless millions of Americans who do not realize to what an extent the welfare of our armed forces in the Pacific during World War II was dependent upon the activities of the Bureau of Science.

The noise of the insurrection had not entirely died away and the "days of the empire" had not yet been succeeded by the civilian regime when a small detachment of the soldiers of peace arrived upon the Philippine scene. Unheralded and, for long years ensuing, little known, armed not with rifles, but with microscopes and test tubes, they went silently to work. Adorned with no gold braid, but with plenty of degrees (about which the average scientist cares little), they set to work, biologists, chemists, entomologists, geologists, and technicians, preparing for the campaigns against ignorance, disease, and the devastating forces of nature.

Under the able leadership of two men from the University of Michigan, they deployed into hospitals, swamps, mines, across rice fields into disease-ridden villages, onto mountaintops, into caves and bordering seas. They studied malaria, earthquakes, typhoons, and volcanic eruptions. Nothing was too small or too large for them to tackle. Often baffled by ignorance, mistrust, lack of equipment, political expediency, ill-health, and prodigious physical fatigue, they struggled on in the age-old battle of man against the unknown. They asked for and expected no medals for Distinguished Service; they merely craved the chance to explore in their chosen fields, the opportunity to push aside the iron curtain of ignorance in a new-old land where man for centuries had been at the mercy of the overlords and of nature in the raw.

Other groups, the liberating armies, the valiant "Thomasite" teachers, civil administrators, had preceded them and done exceptional work. Their achievements have been given proper acclaim, but the men of science have for the most part gone unnoticed by their countrymen in the homeland.

WHEN I went to the Philippines in 1905 as geologist in the Mining Bureau, there was already in existence a bureau known as the Government Laboratories. In 1906 Governor General William Cameron Forbes, one of the best Governors we ever had in those faraway possessions, reorganized the entire galaxy of bureaus. As a result, all

bureaus carrying on scientific research, except in forestry and agriculture, were merged into one bureau to be known henceforth as the Bureau of Science. Our Mining Bureau was one of these and became the Division of Mines in that institution.

The new Bureau of Science building was erected about 1904 at the corner of Taft Avenue and Calle Herran, in the newer part of Manila south of the Pasig River and outside the ***Intramuros***, or "Walled City." The main building had two towers and was of wood and plaster, but later concrete wings were added, one of which was occupied by the Mining and Fisheries divisions and the library. This library, incidentally, became the leading scientific library in the Far East.

The two men chiefly responsible for the foundation and development of the Bureau were Dean C. Worcester, Secretary of the Interior in the Philippine Insular Government, and Paul C. Freer, Director. Worcester had, while on leave from the University of Michigan back in Spanish times, toured the islands as zoologist in the Bourns (Menage) Expedition and later was appointed by President McKinley a member of the first Philippine Commission. He was easily the best-informed person on the Philippines, in or out of those islands. Freer, formerly a Professor of Chemistry at Michigan, was both a Ph.D. (Munich) in chemistry and an M.D.

When the Bureau was created, cynical businessmen made sly cracks about it and referred to it as the "Bureau of Silence," probably because its research men were too busy to indulge in much talk. Later these same businessmen came to regard it as one of the most important agencies of the government.

The principal divisions were the following:

1. Biological Laboratory.
2. Division of Inorganic Chemistry.
3. Division of Organic Chemistry.
4. Division of Ethnology.
5. Division of Mines.
6. Division of Fisheries.
7. Division of Entomology.
8. The Library.
9. The Service Shops.

The Director and the Chiefs of Divisions were the administrators of the work of the Bureau.

Following are some of the outstanding problems and pieces of research that came under my notice in the years 1906–22: Perhaps first to be mentioned should be the long years of research on tropical diseases, especially malaria, since that research was the basis of much of our knowledge for combating this disease during the war campaigns in the Pacific. This work was directly under the supervision of Richard P. Strong (later to become Professor of Tropical Medicine at Harvard), who made the recent revision of Stitt's monumental work in that field.

Next should be cited the ethnological work begun under Jenks, who became Professor of Anthropology at the University of Minnesota. This work was supervised by Worcester himself, though his chief job was the administration of the non-Christian tribes. Much of our successful dealing with these backward peoples was due to the background of such research in ethnology and anthropology conducted by the men of this division. The Spaniards had never been able to deal successfully with the natives, largely because their methods were those of the seventeenth or eighteenth century. Even today some other Western nations still use these outmoded procedures.

Worcester was called The Great White Apo, or "chief." He was a large man, physically and mentally, and sometimes a hard taskmaster. Many, even among his own countrymen, hated him, but everyone respected him.

Researches on foods carried on by the Bureau led eventually to the establishment

of a pure food laboratory and the passage of a pure food and drug act, which undoubtedly played a great part in the improvement of the health of the native population.

In Spanish times there had been some scattered mining, but it never added more than a few thousand pesos to private or government coffers. Through the activities of a band of hardy American prospectors, aided by the work of the Division of Mines, this industry grew tremendously, and in the years 1934–40 the islands enjoyed a major boom in mining. We must, however, give the principal credit to the large operators, chiefly from Colorado and California. In 1940 the Philippine Islands produced more gold than did Alaska.

Fundamental researches in stratigraphy and paleontology led to exploration for oil. Although no appreciable commercial supply of oil had been produced up to the time of the Japanese invasion, enough work had been done to indicate that the Philippines may someday produce a fair amount of petroleum. Other fundamental investigations on iron, coal, and cement materials, to say nothing of studies in general geology, could be mentioned but would take up too much space here. These are embodied in a fairly comprehensive volume of six hundred pages on the *Geology and Mineral Resources of the Philippine Islands*, published in 1925 as a special monograph of the Bureau.

The pages of the *Philippine Journal of Science*, a journal circulated all over the world, contain articles in almost every branch of science and are referred to by any scientist who is faced with problems relating to tropical lands and peoples.

WHAT about the men who worked in the Bureau of Science? We have already mentioned Richard P. Strong, the biologist. With him were Walker, Musgrave, and others well known to students of tropical diseases. Gilbert N. Lewis, a chemist, later became head of the Department of Chemistry at the University of California and was elected to the National Academy of Sciences.

Three other chemists deserve special mention: Robert R. Williams, who started as assayer for the Mining Division, is now Chemical Director of the Bell Telephone Laboratories in this country. He has won several national awards for his outstanding research in collaboration with his equally distinguished brother, Roger Williams, of the University of Texas. Robert Williams was the first to synthesize vitamin B_1, thiamin chloride. Alvin Cox, perhaps not so well known, did some very important work in general chemistry and on Philippine soils. He has become a consultant in California. Benjamin Brooks is another member of the chemical divison; he has made notable contributions to the chemistry of petroleum and is distinguished in that field.

Alvin Seale, one of the leading ichthyologists, who came from the famous school of naturalists led by the late David Starr Jordan, of Stanford University, later became superintendent of the Steinhart Aquarium, of San Francisco. Incidentally, Seale has recently published a book entitled *Quest for the Golden Cloak* (Stanford University Press). This is a fascinating account of his early explorations in the Southwest Pacific from 1900 on.

When Seale left the Philippines, he was succeeded by Albert Herre, who carried on Seale's good work. Herre subsequently became Curator of Fishes at the Stanford Museum. He has been a member of several large exploring expeditions in the Pacific, notably the one sent out from the Field (now Chicago) Museum of Natural History on the *Illyria*, across the Pacific from Panama to New Guinea. He is at present on an expedition to the Andaman Islands.

E. D. Merrill, another National Acad-

emician, who headed the botanical division, became the leading authority on tropical botany and is now Director of the great Arnold Arboretum at Harvard. Associated with him was E. B. Copeland, who did yeoman work in the islands in the early days. Today he is perhaps the world authority on coconuts and rice. He founded and became the first Dean of the College of Agriculture of the University of the Philippines, at Los Baños.

Closely associated with Merrill in botany were five men of the Bureau of Forestry. These were Curran, Whitford, Foxworthy, Matthews, and Fisher. They spent much of their time in the Bureau of Science and were virtually research associates of that institution. In the field of forestry they all became distinguished. Foxworthy became a special investigator for the British in Malaya; Whitford did special work for the Firestone Tire and Rubber Company on rubber in the islands; and Fisher won considerable acclaim for his bringing of Cinchona seeds out of the islands while he was being hunted by the Japanese.

Among the geologists were two outstanding names: Henry Ferguson, now one of the leading geologists of the U.S. Geological Survey; and Wallace E. Pratt, who has just retired as Vice-president of the Standard Oil Company of New Jersey. Both of these men, by their careful work in the islands, early demonstrated their high scientific qualities. The story of Philippine geology would be very incomplete without their fundamental work under very difficult conditions.

We should not omit mention of one Filipino geologist, Leopoldo Faustino, one of the very best of the young native scientists. Unfortunately, his promising career was cut short by his death from tuberculosis. Faustino's work on Philippine reef corals, begun under the supervision of T. Wayland Vaughan while Faustino was a student at Stanford, is the only contribution to that subject today.

In addition to these men and others less well known, many researchers from foreign lands came in a continuous stream to work for shorter or longer periods in the Bureau of Science. One of the most notable publications issued from the Bureau was the *Report on the Manchurian Bubonic Plague*, under the direction of Dr. Strong. This study on the ground was conducted by an international commission.

Now the old Bureau is gone; nothing is left but shattered walls; type collections and irreplaceable books were destroyed by the ruthless barbarians from the north. Nothing left but memories? Nay, the old spirit of research must still linger there, and we hope the Filipinos will look on these ruins as a shrine of science. The influence of Worcester and Freer will long be felt in those islands, and Americans on this side of the water may someday realize that here was an institution that was a beacon of light whose rays will illumine in time many of the dark corners of the Far East.

THE PSELAPHID AT HOME AND ABROAD

By ORLANDO PARK

Dr. Park (Ph.D., Chicago, 1929) is Professor of Zoology at Northwestern University. He is a noted ecologist with entomological leanings. He has two major research interests: the analysis of activity of animals and the study of beetles of the family Pselaphidae. In 1943 he was President of the Ecological Society of America.

IF ONE walks through a forest in the Chicago region in search of mushrooms, flowers, picturesque photographs, a glimpse of chipmunk or warbler, or to enjoy the quiet shade, more than a little of the unconscious relaxation is afforded by the yielding, leafy rug beneath each step.

It is with this moldering layer, the carpet of the forest floor, that we are concerned initially in our prying into the biology of a family of small beetles known as pselaphids. To appreciate these insects they must be fitted into the whole picture. We must begin with their habitat, this leaf-strewn carpet, not merely because it is important, but because it is vital to the forest.

Throughout the year the ground is the recipient of organic debris, of bits of bark, twigs, flower parts, fruits, seeds, leaves, and the excreta of animals or their dying or dead bodies. This diverse material accumulates, in season, from the largest tree or mammal to the smallest herb or invertebrate. As a tree dies from old age or disease, or is struck down by lightning or wind, it falls to the forest floor; in time it and its rooted stump add substance first to the carpet and then to the soil. Especially notable is the autumnal fall of leaves from the forest canopy. By weight of numbers, these leaves give a characteristic aspect to the floor and add materially to its thickness and potentiality.

These deposits must be maintained if any forest is to flourish; if they decline in quality or quantity beyond a subsistence level, the forest declines and eventually perishes. When these organic materials are properly broken down and combined they form humus and eventually mix with mineral soil to form soil which provides a continual source of food for the forest plants. These plants are eaten by forest herbivores, such as aphids, white-footed mice, and, formerly, deer. In turn the herbivores are devoured by forest predators, such as the pilot black snake, weasel, and the now rare bobcat.

Furthermore, this organic carpet serves as an insulating layer against extremes of weather. It is relatively slow in cooling at night or in autumn, and relatively slow in warming in daytime or in spring. This means that the forest is cooler in summer and warmer in winter than adjacent external areas. Again, the spongy leaf mold holds water well, preventing rapid runoff and at the same time resisting erosion of the rich soil beneath. Many organisms find shelter here; some live in the leaf and log mold the year around; others enter this situation to hibernate.

The relation of the leafmold carpet to the forest as a whole is not so simple as it sounds. In order for the plants to obtain their food this biochemically complex layer must be separated and recombined into relatively simple mineral salts. In other words, the floor debris must decay. This is not possible without bacteria, and myriads of microbes labor ceaselessly at this essential and diversified task. This humus is at the same time the food of bacteria and fungi, but this food is formed, bit by bit, from the floor litter above, which in turn is derived from the forest flora and fauna.

Thus many organisms, from the tall trees, such as oak, elm, maple, and beech, to the short herbs, such as the violet and spring beauty, are engaged in production of plant

protoplasm. By means of the green chlorophyll of their leaves, they produce carbohydrate by photosynthesis. For this they need sunlight, water, and atmospheric carbon dioxide. Inorganic salts of many kinds, including those of nitrogen, sulphur, and phosphorus, are absorbed by their root systems from the forest soil and are synthesized into proteins.

Consequently, in this revolving cycle, inorganic salts are taken from the soil by plants; the plants synthesize protein and carbohydrate, die, and eventually are transformed by a complicated course of reactions into salts by bacteria and fungi. These parts of the cycle are more easily comprehended; they are important, but not independent of the rest of the food web. Plants must be fertilized by wind, or by animals, chiefly insects, and they must be dispersed, chiefly by insects, birds, and mammals. Still more vital, their falling leaves and other parts, which are to make up the bulk of the organic soil, must be first broken up, drained, dried, moistened, aerated and chewed up, swallowed, transported, and otherwise treated to allow the bacteria, fungi, and soil protozoans to produce the mature soil from which the plants can draw food. This latter phase is a multiplex industry in which imponderable numbers of animals cooperate—earthworms, mites, insects, millipeds, moles, and many others.

All this activity by forest animals and plants gives a concrete reality to the forest; it ceases to be a grove of trees and becomes a cooperating unit, a forest community. The community needs water and sunlight, and a place to grow, but beyond this minimum it is self-sustaining. That is, the component animals or plants cannot live in a vacuum, as it were, since each kind must have food. Bacteria die if their sources of supply are absent, just as readily as do trees without inorganic salts or aphids without plant sap. Food chains, then, are essential, and where food chains interlace and anastomose a self-sustaining community is produced. This is life at its level of survival.

Since neither space nor time is at hand to study all the component organisms of such a community, it will be instructive to examine one group of soil-inhabiting arthropods, the Pselaphidae.

The pselaphids are minute beetles, composing one of the families of the vast beetle group—the Coleoptera. They articulate with the forest community at the point where the heterogeneous floor litter is being transformed into forest soil. These beetles perform no task that is exclusively their own, and in any one year or in any given community they are not a predominant influence. Despite this lack of drama, pselaphids share with numerous, similarly unsignalized, insects an essential role in the formation of humus: a strange, inverted role to be discussed presently.

Pselaphidae are a large family of small beetles. As with other beetles, they have chewing jaws, and have the first of two pairs of wings hardened into a pair of wing sheaths, or elytra. Most beetles have the elytra extended posteriorly to almost or quite cover the abdomen, but the pselaphids have short elytra, so that usually five abdominal segments are exposed (Fig. 1). This brachyelytrous condition is very uncommon in beetles, very few families having short elytra. Despite this fact, difficulty is to be expected in separating pselaphids from their close relatives, since the brachyelytrous rove beetles, or Staphylinidae, make up one of the largest families of beetles, in excess of 20,000 species, and resemble the pselaphids. These two families, the Pselaphidae and the Staphylinidae, probably evolved from a common ancestral stock. They have many structural features in common, but may be distinguished readily by a student who is familiar with a combination of characters. The staphylinids have a flexible abdomen with 7 or 8 segments usu-

ally exposed, and their 6 feet, or tarsi, have 3-5 segments. The pselaphids have a rigid abdomen, without dorsoventral movement and with usually 5-6 segments exposed; their tarsi always have 3 segments.

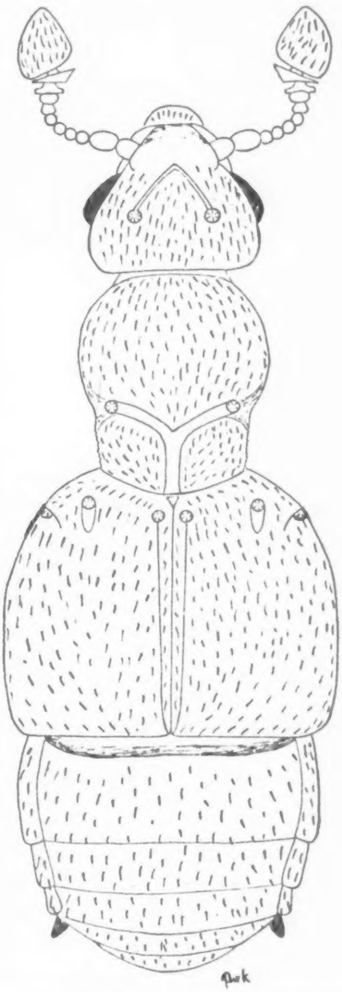
Pselaphids are quite small, even for insects. Their average size is about 1.5 mm. (.06 inch). Some species range down to 0.7 mm., as, for example, *Dalmosella tenuis* Casey and *Thesiastes pumilus* (LeConte), of North America. Others are relative giants; for example, *Hamotus ecitophilus* Raffray, which lives with the voracious army ants in Brazil, has a length of 5.5 mm.

The pselaphids are entirely terrestrial beetles. Their geographic distribution is almost cosmopolitan. This aspect of their biology, the zoogeography of Pselaphidae, is a fascinating study within itself since it deals, not alone with the known distribution of species populations, but attempts to find solutions to questions having to do with past distribution, present trends in dispersal, and why certain dispersal patterns or pattern fragments exist and how they were formed. This involves a great deal of collateral information on the biogeography of plants and other animals, meteorology, oceanography, paleontology, geography, and many special aspects of zoology.

Although pselaphids are represented by numerous species, in many parts of the world, their zoogeography can be discussed only in the most general way. The reason for this is that most of the known species are represented by specimens from single localities. It will require much collecting, the analysis of many field records, and the description of many new species before our knowledge is sufficiently complete to warrant an adequate treatment of their distribution.

In general terms, biologists have divided the earth into six zoogeographical regions, each with its distinct assemblage of animals, its fauna. These regions and faunas are the Palaearctic, Nearctic, Neotropical, Ethiopian, Oriental, and Australian. Although these regions were established primarily for birds and mammals, they represent six more or less well defined pselaphid beetle faunas.

The Palaearctic region has been longest studied (since about the end of the eighteenth century) with respect to pselaphids, but with great irregularity and by only a few specialists. It is the best known of the six regions and includes all of Europe, Asia north of the Himalayas and east to the Pacific Ocean, and extends beyond the



After Park, 1945, Chicago Acad. Sci.

FIG. 1. *CUPILA MEXICANA* PARK

A NEOTROPICAL PSELAPHID BEETLE.

Mediterranean into northwestern Africa to include Morocco, Algeria, and Tunisia.

The Nearctic region is more closely related to the Palaearctic than to any other. It is less well known, having been studied by still fewer specialists and only since the middle of the nineteenth century. This region embraces almost all of North America. Its pselaphids extend southward, along each coast of Mexico about to the Tropic of Cancer, and in the interior of Mexico down the high Central Plateau to the Isthmus of Tehuantepec.

The Neotropical pselaphid fauna shows little affinity with that of other regions. Its large size as now known is but a small token of its real extent. This region extends from the Argentine pampas northward to include all of Central America and Mexico up to an irregular junction with the Nearctic fauna, all of the Antilles, and the tip of peninsular Florida. It has been studied only since the end of the nineteenth century.

The Ethiopian fauna is also little known. The pselaphids characteristic of this fauna are found in all of Africa, save for the northwestern area colonized by Palaearctic species. Provisionally, as concerns these beetles, it includes the large island of Madagascar. There are some indications of pselaphid affinity between the African fauna and that of adjacent Asiatic areas. Thus, several genera, or groups of allied species, have either the same, or related, species occupying Abyssinia on the one side and Palestine or the western border of Arabia, on the other.

Madagascar is usually included with the Ethiopian region. The French expert, Achille Raffray, who, before his death in 1923, did more for the study of pselaphids than any other person, believed that the Madagascan pselaphids were the most isolated of all of the world faunas. Certainly Madagascan pselaphids show little affinity with those of Africa, despite geographic proximity. We shall return shortly to this matter.

The fifth region, the Oriental, is similarly poorly known in contrast, to Europe, say, but it contains a rich pselaphid fauna. This fauna extends from India on the west, south of the Himalayas, to the Pacific Ocean, up the Chinese coast and southward to include the Malay Peninsula, Sumatra, Java, Borneo, and the Philippine Islands. Many new kinds of pselaphids may be expected from this area. The separation of pselaphid faunas on the north, between the Palaearctic and Oriental regions, is not worked out, and the numerous islands have been little studied.

The last region, the Australian, includes New Zealand, the Moluccas, Australia, New Guinea, and New Caledonia and extends eastward to embrace the Fiji Islands. As noted above, future study must be relied on to draw more understandable boundaries between the Oriental and Australian faunas.

The family Pselaphidae is divisible into two subfamilies, the Pselaphinae and the Clavigerinae. The two subfamilies vary greatly in size: the Pselaphinae in general are more primitive in structure, that is, more like staphylinids, and number about 4,800 known species; the Clavigerinae number some 200 species and live only in the nests of ants. This latter habit will be examined later in some detail. For the present we may study this small subfamily with respect to the forms found in the six zoogeographic regions outlined above, and especially the forms confined to these regions, i.e., "endemic" to them, as an example of pselaphid dispersal.

A study of this table brings out a number of interesting comparisons. With respect to general distribution, the Palaearctic and Nearctic regions contain about three-fifths of the land mass but only 5 genera and 49 species; the other four regions, with about two-fifths of the land mass, contain 52 genera and 151 species. The Palaearctic and

Nearctic are much better known than the other regions, so the conclusion drawn is that the tropical regions of the earth hold an overwhelming preponderance of clavigerids.

One of the unsolved questions is the great disparity in number of species of clavigerids between the Palaearctic and Nearctic regions. The former has been better studied, but not so much so as to account for 75 percent excess of species, especially since both regions have few genera. A more probable answer lies in the wide distribution and general adaptiveness of the Old World genus *Claviger*.

The 3 genera in the Palaearctic are *Claviger*, with 36 species in Europe and the Near East and 1 species in Algeria; ***Diartiger***, with

TABLE 1

REGIONAL DISTRIBUTION OF CLAVIGERINE PSELAPHIDS

	Palaearctic	Nearctic	Neotropical	Ethiopian	Oriental	Australian
Total Genera	3	2	3	30	11	8
Endemic Genera	2	1	2	28	8	6
Species	40	9	22	56	14	61

2 species in Japan; and *Articerodes* with a species in Mesopotamia. The 2 genera in the Nearctic are *Adranes*, with 6 species in the United States, and *Fustiger* with 3 species.

Thus no genus is found in the two regions, and *Claviger*, restricted to the Palaearctic, contains 37 out of 40 species known from this vast area.

When we extend this examination of geographic restriction, or endemism, to the six zoogeographic regions, it will be seen from Table 1 that all regions have a high proportion of restricted genera. This suggests, but does not prove, great isolation, involving geographic and ecological barriers. This is brought to light more vividly in Table 2.

In this second table it should be noted that out of 50 clavigerid genera, only 4 cover more than one region. A single genus, *Fustiger*, may be thought of as widely distributed. This genus occurs in five of six regions. Strangely enough, it is absent from the Palaearctic, which may be a consequence of direct competition with *Claviger* for suitable ant hosts or an indirect effect involving the restriction of its usual host ants. Climatic barriers do not appear to be involved, since *Fustiger* is established in the Nearctic. *Fustiger* has a large predominance in the Neotropical region, a region, paradoxically, poorest in clavigerids. Such a dispersal pattern might suggest that *Fustiger* arose in the Neotropical region, spread through North America into the Palaearctic region, where

TABLE 2

CLAVIGERINE GENERA COMMON TO TWO OR MORE REGIONS

Genus	Species per Region					
	Palaeartic	Nearctic	Neotropical	Ethiopian	Oriental	Australian
Articerodes	1	0	0	2	2	0
Articeropsis	0	0	0	1	1	0
Clavigeropsis	0	0	0	1	0	2
Fustiger	0	3	20	3	1	5

from extinct (or undiscovered) Asiatic stock it spread into the Oriental region and from here into Africa and Madagascar to the west and the discontinuous Australian region to the east.

This is one interpretation of *Fustiger* distribution. It assumes that the region of largest number of species is the ancestral home of the genus. Let us examine the pattern from another aspect and assume that *Fustiger* is a very old genus which may not withstand competition with more modern genera and hence is extinct or impoverished in its original home and able to flourish only at the periphery of its range. This type of dispersal may be called Matthewsian,

after W. D. Matthew, who set forth the importance of this type of distribution.

According to this view, *Fustiger* arose elsewhere and has been pushed into the Neotropical and Australian regions. In the former area it has flourished, and even probably given rise to the other two related neotropical genera (*Pseudofustiger* and *Neofustiger*). In the Australian region, it is not found in Australia itself, where the large genus *Articerus* is endemic with 49 species, but only in the remote Fiji Islands, where there are 5 species of *Fustiger*.

The case of *Fustiger* has been given as an example, and two of the possible interpretations have been suggested to emphasize how

TABLE 3

CLAVIGERINE RELATION BETWEEN MADAGASCAR AND AFRICA

	Ethiopian Region	Africa	Madagascar
Total Genera.....	30	12	19
Endemic Genera..	29	11	18
Common Genera..	1	1	1 (*Fustiger*)
Extraregional Genera........	2	2	1 (*Fustiger*)
Total Species.....	56	27	29
Endemic Species..	55	26	29
Extraregional Species........	1	1	0

little we know about pselaphid distribution and evolution.

To return briefly to the Ethiopian region, this poorly explored area should be examined in the light of Raffray's view as to the distinctness of the pselaphids of Madagascar.

From this third table it will be seen that Madagascan clavigerids are as distinct from those of Africa as from those of any other region. They are more distinct than those of Africa are from the Palaearctic, since one species, *Articerodes syriacus* Saulcy, ranges from Syria and Mesopotamia into Abyssinia. The only common bond is the widely distributed genus *Fustiger* previously noted. In time a seventh zoogeographic region, the Malagasy region, may have to be added for the peculiar pselaphid fauna of Madagascar, as has been done for certain other groups.

LET us turn our attention from the distribution of the pselaphids in the zoogeographic regions to their habitat relations. These beetles are known from the fringes of the northern conifer forests of both hemispheres southward to the pampas of Argentina, the southern tip of Africa, and Australia. All continents and, where they have been looked for by entomologists, all major island groups have their pselaphid faunas with one exception. Despite repeated search, no pselaphids have been found on the Hawaiian Islands.[1]

Their absence from these islands is not unusual. This distribution can be duplicated for many groups of plants and animals and, among diseases, human malaria. Pselaphids could not fly to the Hawaiian Islands from, say, the Fiji group or North America; the ocean currents are not advantageous for these beetles to effectively colonize these islands by natural floating rafts.

Pselaphids occur from sea level up to the Temperate Zone on mountains; for example, to at least 10,500 feet on Totonicapam in Guatemala. Present information shows an altitudinal distribution of species of pselaphids in the usual zonal pattern in Guatemala and Mexico, although the data are too few in a quantitative sense to do more than outline this problem of vertical distribution.

Other pselaphids descend into deep caves and are structurally adjusted for a cavernicolous life; for example, certain species of the genera *Macrobythus*, *Glyphobythus*, *Apobythus*, *Linderia*, and *Lophobythus*.

[1] Personal communication of Dr. Eliot C. Williams states that he found no pselaphids in the Hawaiian Islands as late as April 1945. This lack was corroborated for Dr. Williams by Dr. Elwood C. Zimmerman, of the Bishop Museum, Honolulu, and serves to substantiate the older literature.

Nevertheless, the family is preponderantly tropical. Of the 5,000 or more species, some three-fifths inhabit the Torrid Zone. The Western Hemisphere, for example, holds 1,348 known species. Of this number, 384 species are known north of the Tropic of Cancer and 964 south of this general limit between the 2 faunas.

Pselaphidae, then, are to be found over most of the earth. In this great expanse of territory they occupy two chief habitats, the leaf and log mold of forest floors, and the nests of ants and termites. Both deserve consideration.

About 85 percent of the species of Pselaphidae live in the leaf and log mold of the forest floor. Such preponderance should give to the family the common name "leafmold beetles," but several other families of beetles coinhabit the floor litter, and, early in the study of the pselaphids, the relatively few that live with ants were called "ant beetles." The common appellations "ant beetle," "antlike beetle," and "antloving beetle" have been applied to the family since that time.

The leafmold-inhabiting pselaphids are nocturnal or, more exactly, crepuscular. Most of the day is passed quietly in the moist, irregular, dimly illuminated mold passages. Near dusk they become relatively much more active and walk or fly in search of food, water, or mate. This activity is usually concentrated into the period from sunset up to 10:00 P.M.; some species continue their activity to midnight; a few are active in the early hours before dawn. They drink from the droplets of moisture on the mold. The pselaphids are predacious. They feed upon a variety of animals. These latter include any they can overpower with their forelegs and sharp jaws; for example, small insect larvae, injured earthworms, small flies (*Sciara*), and especially mites.

Their mite-devouring proclivity has been known for a long time. It was known to one of the earliest students of the pselaphids, Henry Denny, who gave the food of British pselaphids in 1825 as "mites, in damp situations." My students and I have observed pselaphids eating mites, in laboratory nests, from numerous localities in the United States and in the American tropics.

The humus and floor debris swarm with free-living mites and free-living stages of parasitic mites belonging to many families, among which may be mentioned the Oribatidae, Hoplodermatidae, and Parasitidae. These mites are usually minute, between a fourth to a half the size of a pselaphid. The majority of such mites are herbivorous. They infest the floor in force. I have counted them in the coniferous forests of Wisconsin, the deciduous forests of Indiana, and the rain forest of Panama. They may occur in numbers, up to 7,000 mites per kg. of mold. Since their leafmold-eating is an important factor in litter reduction, mentioned in the opening paragraphs of this article, these mites are important in the well-being of the whole forest community.

Such mites are one of the chief foods of the leafmold pselaphids. A beetle overtakes a mite, holds it down with its foretarsi, and chews it with its jaws. Since the mites are important in humus production, this predation by pselaphid beetles might seem to have a negative value. Destruction of mites may appear to invalidate the view that their enemies are beneficial to the forest community as a whole. Consider, however, that if these mites and their numerous allies in litter reduction were not held in check, the litter would be too rapidly reduced.

Such a situation might lead to an initial period of increased bacterial activity and plant growth. Nevertheless, a time would come when the invaluable humus reserve would be depleted, when the floor would become exposed to erosion and would have less insulation. There would be the annual crop of debris and leaves, but no reserve. This would lead eventually to community disaster.

Consequently, in the over-all picture of the complex operations which I refer to as community metabolism, predators are as important as herbivores. The pselaphids and their allies in predation hold the mites of the leaf and log mold, and their allies in litter reduction, in a delicate biological balance.

The leafmold pselaphids are well adjusted for their life in the litter and mold of the forest floor. This adjustment is both structural and functional.

They react positively to a relatively high amount of atmospheric moisture. If pselaphids are placed in a gradient of relative humidity, from, say, 30–80 percent, they aggregate in the upper third of the gradient. If they are placed in a glass-covered dish, on a sheet of moistened filter paper, they walk about while the sheet is giving off its moisture into the confined space. But gradually through the day the filter paper dries out and the relative humidity of the enclosed air decreases. The beetles become more and more active, running about until, by trial and error, they find the last wet patch on the filter paper. They make short excursions to and from this oasis, gradually forming a place aggregation on the moist spot. Finally, the moisture evaporates and the pselaphids die at, or near, the moist area.

Such behavior is in keeping with their natural habitat in the moist floor mold and litter. It tends to keep them at, or near, the forest floor.

They react negatively to strong light. If pselaphids are placed in a gradient of light, from about 100 foot-candles intensity down to darkness, they wander about and, by trial and error, select the dark third of the gradient.

There are no experimental studies on the visual acuity of pselaphids. On the structural side, the pselaphid visual equipment is not so effective as that of the many insects that capture their food while flying, like dragonflies. Most of them have only 60–100 facets per eye. This is a very low number for insects in general. Species of pselaphids that live in deep leaf mold, beneath boulders embedded in the soil, or in caves, have eye size and number of ocular facets reduced. Thus among the species of the *Rhinoscepsis* the eyes vary, from 8 facets per eye in a Mexican species to 30 facets per eye in a Brazilian species. *Bibrax* from Panama has eyes with only a single facet, and *Arianops* of Appalachian North America has no eyes at all.

In other genera, the eye development is correlated with sex. Thus 2 large American genera, *Jubus* (with 49 species), and *Arthmius* (with 104 species) have eyes with significantly fewer facets in the female sex. This is a not uncommon feature in the family, although by no means the general rule. In some genera, the eye reduction in the female sex is even more pronounced. Thus the species of *Glyphobythus*, *Apobythus*, *Linderia*, and others, of Europe, have females with vestigial eyes.

The relatively poor optical equipment of leafmold pselaphids is in harmony with the reduced light intensity of their habitat. In forests, when the foliage is at its maximum and the pselaphids are in their active period of the year, the floor is usually dimly illuminated (25–50 foot-candles) during the day. Under such conditions the beetles would tend to remain in areas of deep shade.

In those genera in which both sexes lack eyes, or the female sex has reduced eyes or no eyes at all, dispersal would be very slow. In the first case, both sexes would move into adjacent areas with difficulty; in the latter cases, the species could not be established by the male alone.

The general effect of these adjustments, that is, the tolerance for high relative humidity and low light intensity, coupled with a relatively poor ocular development, would be a natural tendency for the populations of these beetles to keep to the forest floor or to caves.

Correlated with this is their period of

activity during the dusk and night hours. When active, pselaphids all walk rather well, and many fly. They may be taken by net during the evening, often in great numbers. *Biblopleclus*, for example, has been taken in Kentucky, from a moving automobile with attached nets, between 6:00 P.M. and 8:00 P.M., by Dr. H. E. McClure. This same method has been used by Dr. Alfonso Dampf to capture Mexican pselaphids in flight at sunset.

Most pselaphids have wings. These flying organs are delicate, membranous structures which, when extended, are about as long as the body; when at rest the wings are folded up into a square and tucked beneath the hard elytra. Some pselaphids have vestigial wings, too short and narrow for flight; in some cases poor flight is associated with vestigial eyes.

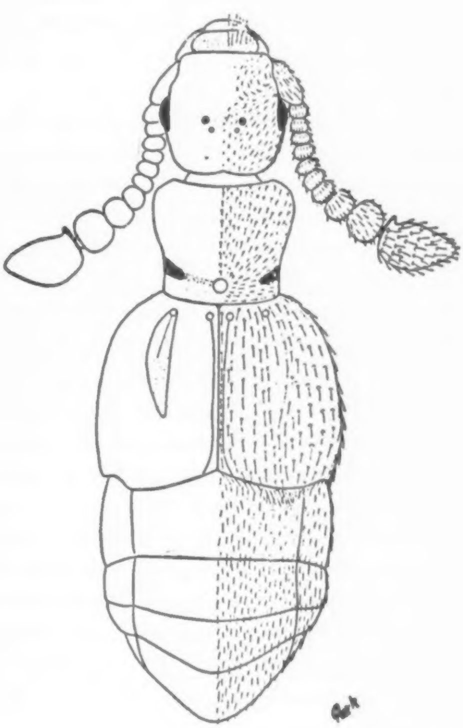
In common with many other nocturnal animals, pselaphids are attracted to lights at night, especially in the tropics. This is not a fully explained response.

Another behavior of many leafmold pselaphids is their "feigning death," "playing possum," or "letisimulation." When they are uncovered in their native habitat, some genera (*Melba, Rhexidius, Tmesiphorus*) crouch close to the substratum, with their legs and antennae folded tightly beneath their bodies. Experimentally, this letisimulation may be induced by vibration of the laboratory habitat, or by touching the beetles. The usual period of such feigning is 30–70 seconds. On repeated stimulation the duration of the death-feigning response is gradually reduced.

What information or stimulus to orientation is unavailable to leafmold pselaphids as a consequence of their deficient optical equipment is probably obtained through the sense of touch and by chemoreceptors. Whether in their native litter or under the microscope in an artificial habitat, they are seen to be continually twirling their antennae or tapping these organs on the substratum. In addition to these appendages, pselaphids have a pair of maxillary palpi, which are segmented structures growing laterally from a second pair of jaws, the maxillae. When the insects are eating or drinking, these palpi are continually tapping the food or moisture.

Both antennae and maxillary palpi are highly developed in the family as a whole. The name of the family is taken from the genus *Pselaphus*, described by J. F. Herbst in 1792 and derived from the Greek, meaning "I feel my way," in allusion to the very long and peculiar palpi of this genus.

The antennae are usually clubbed, clavate or capitate, the last 2 to 3 segments being abruptly larger (Fig. 2). These organs vary within the family from 2 to 11 segments, and one or more segments may bear deep pits (foveae), or spines. These accessory



From Park, 1946, Chicago Acad. Sci.

FIG. 2. *HAMOTOCELLUS ARAUJOI* PARK

A PSELAPHID ASSOCIATED WITH TERMITES IN BRAZIL.

structures are often found in the male sex only, and in many species reach fantastic proportions.

The maxillary palpi are similarly variable in the whole family. They are almost universally 4-segmented, often very long, and bear an almost infinite series of variations limited to species. One entire group of genera, centering around the Neotropical genus *Hamotus* (89 species), has the last segment longitudinally grooved. From this palpal sulcus a pearly liquid is secreted.

Most pselaphids are covered with "hair," or setae. This pubescence is usually very short, and the individual hairs are sharp-pointed and inconspicuous. There are numerous exceptions to this, and often the setae are so specialized that they may appear to be tactile in function, or to have some unknown sensory role. Obviously, we need much research upon this point before reaching conclusions. A few examples will give the range of variation in pselaphid pubescence.

One whole section of the family (the Ctenistini) is characterized by having the setae greatly flattened and widened, so that each seta is a spade-shaped wafer. In other genera certain special setae have greatly enlarged tips. These hairs may end in a relatively large sphere, or have the tip flattened to form an umbrella-shaped structure. Setae may be concentrated about glandular areas of the body. Finally some few, such as the Japanese *Batristilbus* and the essentially Neotropical *Eupsenius*, are glabrous, that is, lack all pubescence.

What has been outlined in regard to pselaphid anatomy and behavior leads us to the conclusion that these beetles are well suited for a life in the forest floor litter and humus; that, through their predation, they assist in maintaining a balance of forces in litter reduction.

Not all pselaphids inhabit the forest floor. Other terrestrial niches may be sparingly occupied. We have mentioned their residence beneath deeply embedded boulders, usually on the sides of hills or in rocky meadows. Similarly, the cavernicolous habit has been noted. Other species inhabit the unstable vegetation mat of quaking bogs.

Quite a few live in the relatively thin humus and floor of prairie communities and may be taken from bluegrass with a sweep net. An aspect of the predacious nature of meadow pselaphids may become economically important. In the past few years H. W. Stunkard, of New York University, has demonstrated that the oribatid mite genus *Galumna* is the intermediate host of the sheep tapeworm, *Moniezia expansa*. Since pselaphids feed upon mites, *Galumna* included, their predation in contaminated pastures is to be thought of as an ecological deterrent to the dispersal of the vector and its parasite.

All the nonforest habitats seem to be secondary. All are more or less adjusted to fit the living requirements of these beetles, and have some resemblance to the forest habitat niches.

There remains a remarkable habitat penetrated by about 15 percent of the species of Pselaphidae. This is the complex social environment of ant and termite nests. Pselaphids that live in these nests as guests (or "inquilines") are "ant beetles" in truth, and include some of the most highly specialized genera. The contact of ant beetles with social insects has elicited some of the most intricate patterns of insect behavior.

It is not strange that pselaphids should be able to live with ants and termites; many animals do. The relatively uniform air temperature and relative humidity of the host nest, its darkness, and the abundant food supply are ecological conditions that fit the requirements of leafmold inhabitants. There are two apparent objections from the pselaphid standpoint. The first of these is that the food might differ qualitatively from that of the leafmold carpet. The second is

that the generalized leafmold pselaphid must become adjusted to the host; that is, the beetle must be either tolerated by the ants or termites or able to avoid them successfully in the nest.

As to the first of these points, the pselaphid diet is so varied as to kind and condition of the animal eaten that the first problem does not apply to most ant hosts. The majority of ants assemble in their nests a great variety of foodstuffs. Pselaphids inhabiting such nests feed upon the food brought in by the worker ants, and also upon injured ants, ant larvae and pupae, and upon the mites which live in the ant nest and on the ant integument. The food factor presents a more serious problem with respect to the establishment of the pselaphid-host relationship in termites, for termites, miscalled "white ants," have a restricted diet of woody fiber, or cellulose, and this is not a food of the predatory pselaphids.

One may postulate a sudden genetic mutation of a leafmold pselaphid that would endow the beetle with such an array of adaptive features that the species population would fit into the termite society without difficulty, would be unmolested by the host, and could feed on termite exudates, feces, or on sick or immature inmates.

Such a postulate is not the most probable explanation. We may rather imagine that there has been a gradual evolution of guest pselaphids. Each pselaphid species population so involved would be subjected to environmental selection, the selection in this case being made by the social matrix of ant or termite. From this point of view, the primitive mold pselaphids would pass through a stage in which they were facultative, could live in the humus or in the nest at the dictate of circumstance. Gradually, over great periods of time, positive selection for the nest habitat would operate on pselaphid mutants. There would be a tendency for the dark, stable nest climate and the abundance of assorted food stores and immature hosts to produce beetles that had become more and more adjusted to the life of a social parasite, and less adjusted to the mold habitat.

If this general view is tenable, then the ant society, with its more varied and abundant food, should be colonized more often than the termite society, which has its food base in wood fiber and offers fewer feeding possibilities to the invading beetles. The fact is that there are a great many more pselaphids found with ants than with termites. For example, in the American tropics there are 964 known kinds of pselaphids. Of this number, there are 54 species known from the nests of social insects, or 5.7 percent of the fauna. This is lower than in the better known Nearctic fauna and reflects our ignorance of the tropics. Of the 54 pselaphid inquilines, 42 species, or 78 percent, live with ants as "myrmecocoles," and 12, or 22 percent, with termites as "termitocoles."

As to the second objection, the difficulty of adjustment to the host by the pselaphid is met by the fact that a great number of these beetles do live with social insects, thus proving that these beetles have adjusted, and are continuing to adjust themselves, to ant and termite societies. This inquilinous adjustment has arisen in many different tribes within the Pselaphidae, and 2 tribes, the Attapseniini and the Clavigerini, are restricted to this way of life.

Apparently, the role of the pampered guest is neither the result of a sudden genetic change nor the exclusive property of a particular stock.

As expected, some pselaphids are at home either in the forest floor or the ant nest. In the United States we may mention 2 species as examples of this category, *Batrisodes globosus* and *Tmesiphorus costalis*. These species are "leafmold beetles" most of the time but are frequently recorded as "ant beetles" with a variety of different kinds of ants. As species become more adjusted to

ant societies they tend to inhabit the nests of fewer species of hosts, until they become more or less restricted to a single kind of ant, or to a few closely related kinds. The genuine guest (myrmecophile) is not taken at liberty in the humus; the more specialized forms have rudimentary mouth parts and appear to be unable to live outside the host circle.

Many entomologists have worked on ant-beetle ecology; the list of their names is a cosmopolitan one. Such men include Erich Wasmann (Belgium), Alfred Hetschko and Erich Krueger (Germany), H. J. K. Donisthorpe (England), Filippo Silvestri (Italy), E. A. Schwarz, W. M. Wheeler, and H. F. Wickham (United States), Carlos Bruch and Angel Gallardo (Argentina).

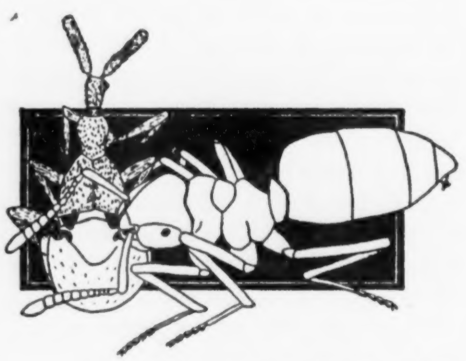
Erich Wasmann, a pioneer in this phase of investigation, gave a classification of the guests of social insects in general, and Wheeler modified this classification in 1910. This modified version, with strict application to the pselaphids, includes two categories, the synoeketes and the symphiles.

The synoeketes are pselaphids that live within the nests of ants and termites without being actively persecuted by the host. Usually such species are indifferently tolerated. Within this category there are many subdivisions, from the facultative forms to those approaching the symphilic condition. There are many pselaphids in this general group, including species of *Batrisodes*, *Rybaxis*, *Cedius*, *Tmesiphorus*, *Ceophyllus*, and *Cercocerus* living with ants, and *Phtegnomus* with termites.

The symphiles, or true guests, are the elite among ant beetles. They include the entire subfamily Clavigerinae, and possibly the remarkable new tribe, Attapseniini, known so far by 2 species living with the leaf-cutting ants (*Atta*) in Brazil and Argentina. The attapsenines have been described by Carlos Bruch and August Reichensperger, but we lack ecological information about them as yet. They are noted here since they are structurally intermediate in many ways between the subfamily Pselaphidae and the subfamily Clavigerinae.

The symphiles exhibit a number of characteristic responses, or "symphiloid characteristics." Their behavior pattern and structural aspect include:

1. A more or less shining, light-colored integument, often resembling the "oily yellowish sheen" of their hosts.
2. Special tufts of long, golden setae (trichomes) that convey a special secretion. This secretion is produced by gland cells at the base of the trichome and is very stimulating to the host, the worker ants frequently stopping their communal activities to lick and suck these golden bundles (Fig. 3).
3. The inconspicuous, highly modified mouth parts: these are fitted for licking, scraping, and sucking, rather than chewing, a struggling leafmold mite.
4. The unusually modified antennae.
5. The deliberate, clocklike precision of their unhurried walk within the hurry of the nest.
6. The habit of twirling the antennae when approached by a host ant.



From Park, 1932, Ann. Ent. Soc. Amer.

FIG. 3. HOST AND GUEST

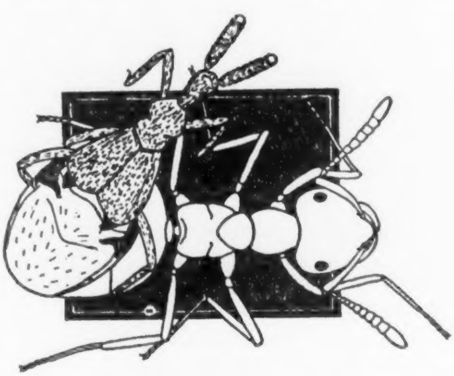
A HOST ANT (*Lasius aphidicola* WALSH) LICKING AND SUCKING THE TRICHOMES OF THE PSELAPHID *Adranes lecontei* BRENDEL.

These features, in combination, are equivalent to a hallmark of the true guest. Some items, such as the elaborate antennae or shining integument, taken alone, are frequently seen in free-living pselaphids.

Of the 200 odd species of clavigerid sym-

philes, 3 are rather well-known, *Claviger testaceus* and *longicornis*, of Europe, and *Adranes lecontei*, of the United States. The day-to-day life of these 3 may be summarized as an example of symphilism.

The beetles are wholly immune from host attack, a condition hard to attain in the Amazon society of most ants. They stalk about the moist, dark galleries, especially the ant brood chambers. When approached by an ant, the pselaphids do not letisimulate or hurry away; rather they pass slowly by, or pause and twirl their antennae, or stop so that the ant must pass over or around. The ants suck assiduously at their trichomes, lick the beetle's integument and scrape at it. This sucking and licking goes on at all hours of the day or night, the ant society being arhythmic. The beetles may be so attended by several ants simultaneously for several minutes at a time. Furthermore, they ride about the nest on the ant's body. This behavior (phoresy) may last for



From Park, 1932, Ann. Ent. Soc. Amer.

FIG. 4. A HITCHHIKER

A PSELAPHID, (*Adranes lecontei* BRENDEL) BEING CARRIED ABOUT THE NEST OF THE HOST ANT (*Lasius aphidicola* WALSH) BY A HOST WORKER.

long periods. Thus an *Adranes* has been seen to climb on the abdomen of an ant and ride her about the nest for ninety minutes (Fig. 4). In addition to licking and sucking the beetle integument and trichomes, the ant workers feed the beetles directly. The ant approaches a clavigerid and, after they have tapped each other with their antenna, regurgitates a drop of liquid food into the mouth of the beetle, just as she would for a sister ant. In return for such treatment, the beetle may strike at the nest society, just

From Park, 1932, Ann. Ent. Soc. Amer.

FIG. 5. TAKING CANDY FROM A BABY

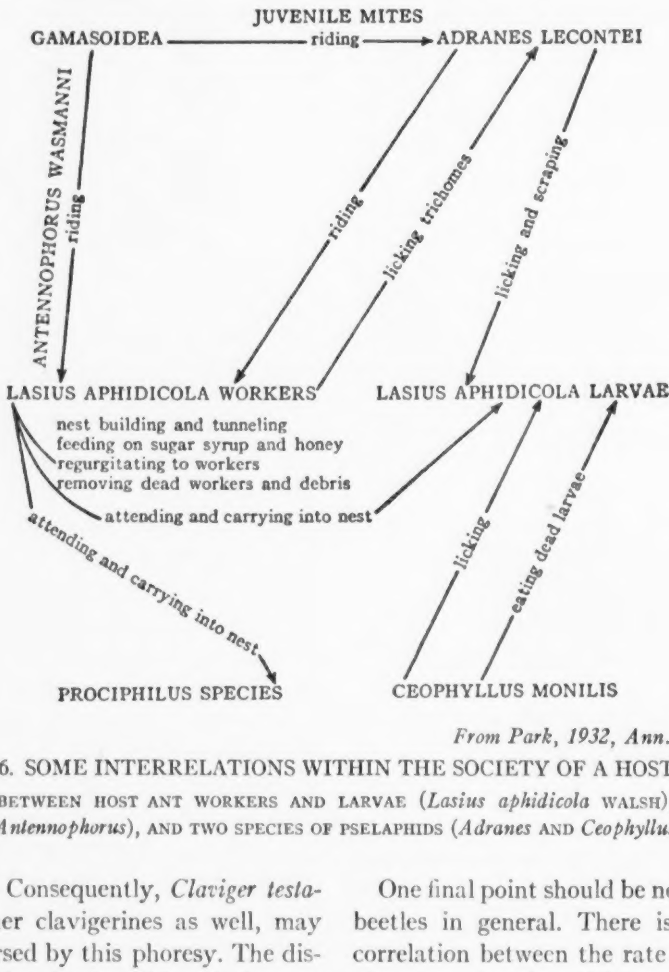
A PSELAPHID (*Adranes lecontei* BRENDEL) HOLDING, LICKING, AND SCRAPING A LARVA OF THE HOST ANT (*Lasius aphidicola* WALSH).

as gangsters and racketeers strike at the human society. Thus, some species haunt the brood chambers and occasionally scrape, puncture, and suck the eggs, larvae, and pupae of the host, or a badly injured worker ant (Fig. 5). This is a very complex pattern of behavior (Fig. 6). The common host of *Adranes lecontei* is the pale yellow *Lasius aphidicola* or its close allies. With this ant live other guests besides the clavigerid, each guest having a separate pattern with every other guest and the host. Thus there is a large mite, *Antennophorus wasmanni*, which rides about on the ants. These mites also ride on the beetles; I have seen mites on a beetle and the beetle in turn perched on a burdened ant.

The species of *Claviger* and *Adranes* have no eyes. As a rule, they are not found beyond the confines of their host's nest. An exception may be noted in their probable method of dispersal. On at least three separate occa-

sions an individual of *Claviger testaceus* has been taken while clinging to a winged male or female ant. It will be remembered that the virgin queen ants and their male consorts compose the reproductive group. Such ants are usually winged. At the mating season these ants leave the parent nests, mate, and the fertilized queen ants found tended by males, at the future nesting spot, breaks off her wings, and begins to lay eggs.

Thus it is difficult to imagine how clavigerids are dispersed without clinging to queen ants, at least for most ant species. It is nearly as difficult to understand how they can be established in a new nest by this method.



From Park, 1932, Ann. Ent. Soc. Amer.

FIG. 6. SOME INTERRELATIONS WITHIN THE SOCIETY OF A HOST ANT

RELATIONSHIPS BETWEEN HOST ANT WORKERS AND LARVAE (*Lasius aphidicola* WALSH), GAMASID MITES (*Antennophorus*), AND TWO SPECIES OF PSELAPHIDS (*Adranes* AND *Ceophyllus*).

new colonies. Consequently, *Claviger testaceus*, and other clavigerines as well, may become dispersed by this phoresy. The dispersal would be slowly achieved since at least 2 beetles, of opposite sexes, or a previously fertilized female clavigerid would have to be present. This raises certain objections. Two beetles have not been reported on the same winged female ant, and the fertilized queen ant usually arrives, unat-

One final point should be noted about ant beetles in general. There is an apparent correlation between the rate of locomotion of a myrmecocole and its ecological role in the host society. That is, symphilism is more or less inversely proportional to speed of movement. A single example must suffice. Five worker ants of *Lasius aphidicola* were clocked for 10 trials, each trial lasting one minute. These 50 trials averaged 52.5 inches

moved per minute. Their synoekete guests (*Batrisodes scabriceps*, *Batrisodes schaumi*, and *Ceophyllus monilis*) averaged 36.3 inches per minute. The symphile, *Adranes lecontei*, averaged 20 inches per minute when undisturbed.

Obviously, a beetle that is subject to host attack cannot perpetuate itself unless it (1) has a prodigious reproductive rate, or (2) can defend itself by physical means, or (3) can run faster than the host, or (4) hides in unfrequented parts of the host nest.

When we have found ant beetles relatively unmolested by the host ants and moving more slowly than their hosts, we have assumed that natural selection is operating upon changes in the heredity of the population. Consequently, natural selection must be regarded as acting as an ecological influence within the complex nest society of social insects.

This may partially explain why the category of persecuted guests (synechthrans) is rare or absent among pselaphids. The pselaphid beetle, with its rigid abdomen and generally slow locomotion, could hardly exist in an ant nest if the beetle were constantly pursued and attacked.

In such a general account, intended to present a group of insects to scientific colleagues, it seems fitting to emphasize the lack of information that is available on the life history of Pselaphidae.

If one brings back for leisurely study an entire ant nest, or a large quantity of forest floor mold, many kinds of adult insects are to be found, including pselaphids, and many insect larvae. These larvae can be identified or reared, in many cases, but one does not find the larvae of Pselaphidae. Why?

Eggs, larvae, and pupae of the related rove beetles, or Staphylinidae, have been described for a respectable number of species. The immature stages are known in many families of beetles with fewer species than the Pselaphidae. The pselaphids, with about 5,000 species, are almost unknown with respect to their life history. Here is a strange thing indeed.

Since 1818, when P. W. J. Mueller began the study of pselaphid beetles in relation to host ants, there has been a paucity of information on the immature stages of these insects. Wasmann, Janet, Hetschko, Schmitz, Peyerimhoff, and Donisthorpe have discussed this problem and have studied *Claviger* carefully, but the larval stages remain unknown. Between 1930 and 1931 the American experts on beetle larvae, Adam Böving and F. C. Craighead, published a critical study on the larvae of beetles, but could identify and illustrate only the larvae of 2 species of pselaphids, *Batrisodes monstrosus* and *Euplectus confluens*.

Whereas there are many species of pselaphids, with the exception of a very few, they are known only from the mature adult stage (the imago). These beetles are widely distributed. In the tropics they can be taken in numbers around lights at night. They can be driven from humus by a gradient of heat, in what is called a "Berlese" or a "Silvestri" funnel. They can be picked out of an ant or termite nest. They are not easily collected and are not common in the usual sense of the term, but the adults can be accumulated with patience and persistence.

Since each adult pselaphid must have hatched from an egg as a minute, six-legged, wormlike stage known as a larva; and since each larva must pass through several periods of growth, with a molting of the larval integument at the end of each growth and differentiation period; and since the final larval stage must pass into a quiescent stage known as a pupa, before the adult emerges from the pupal skin, we should expect to find these several immature stages in the forest log and leaf mold, and in the nests of ants and termites.

At least there should be as many larvae as adults. Theoretically, there must be many more eggs, larvae, and pupae than adult beetles since these immature stages would be subject to destruction by carnivorous insects, bacterial and fungoid disease, and accident. If each species population is to maintain its size, or increase its size, there must be enough immature stages to furnish a margin of safety against such loss, a superabundance of immature animals.

The fact that the immature stages of pselaphids as a whole are almost unknown is thus a mystery. There must be some explanation. Perhaps it is quite simple; for example, some ecological factor operating upon their immature life in a peculiar way, or a physiological requirement, that causes their eggs, larvae, and pupae to be hidden in the humus or in the host nest so securely that we have not discovered them. This would be discoverable in time, by chance or deliberate search of unlikely places. Again, these immature stages may be parasitic for at least some of the species of pselaphids.[2]

Oddly enough, we have both ends of the chain: the mating act of the mature pselaphids, and the just-emerged adult.

I have seen pselaphids mate on several occasions at localities in widely separated parts of the Western Hemisphere, and in such free-living genera as *Batrisodes* and *Dalmosella*, and in the symphilic, blind *Adranes*. I have never seen the females lay their eggs.

The just-emerged adults are not at all uncommon in large collections. When a beetle breaks out of the pupal integument it is soft and light-colored. In the pselaphids, these "callows" are thin-skinned, delicate creatures of an almost uniform light-yellow color. If they are killed and pinned in this condition, they remain light in weight and color, although they become more or less shrunken with time.

The free-living leafmold pselaphids probably live at least a year. In temperate regions mating occurs most frequently in the late spring, between April 15 and May 15. The species probably hibernate as adults in the floor mold. The ant beetles such as *Adranes* and *Claviger* live a long time in captivity. I have kept *Adranes* alive with the host ants for fourteen months; *Claviger* has been kept for as long as three years by Donisthorpe in England and for four years by Janet in Europe.

We must await more information before an over-all view can be held regarding the life history of the Pselaphidae. But these beetles remain with us, a large, diversified assemblage, performing a useful function in the forest community, and generally unknown by biologists.

[2] This is not my view alone. My friend, H. S. Barber, of the U. S. National Museum, expressed this belief in a conversation several years ago.

SOVIET SCIENCE AND POLITICAL PHILOSOPHY

By KARL SAX

Dr. Sax (Sc.D., Harvard, 1922) is Professor of Botany at Harvard. Although his special field is cytogenetics, he takes an active interest in human population problems as did his predecessor, E. M. East. He is a member of the National Academy of Sciences.

EMINENT scientists who have visited Russia in recent years have brought back only glowing accounts of the progress of science in the Soviet Union. In the field of medicine Dr. Hastings, of the Harvard Medical School, found "medical science to be in a healthy state," although he learned of no new practical research developments in medicine that were definitely superior to those of English and American scientists. It seems strange that he did not even mention Bogomolet's longevity serum, which is claimed to double the span of human life!

In an article in THE SCIENTIFIC MONTHLY Langmuir states that Russian physicists are "free from undue political control" and during the war were engaged in theoretical work that would have been prohibited in the United States. It is something of a surprise, however, to learn that Kapitza, the distinguished physicist, seems to be working on increased output of blast furnaces for steel production.

C. E. Kellogg, head of our U.S.D.A. Soil Survey, has nothing but praise for Soviet soil science, according to Waldemar Kaempffert, Science Editor of the *New York Times*. Dr. Crowther, of England's Rothamsted Experiment Station, also praises Soviet agrochemistry. In the field of soil science the Russians seem to be particularly outstanding.

Last fall a well-known scientist, who does not wish to be quoted, told a Boston audience of the great progress of Soviet science, but regretted the "liquidation" of some of Russia's leading astronomers.

It is quite possible that these scientists have given us a true picture of their own fields of science in Russia, but when J. D. Bernal, Julian Huxley, J. B. S. Haldane, and L. C. Dunn praise Soviet biology and genetics, there is some reason to question the conclusions of the other experts.

In the field of genetics we do not have to rely on the reports of "experts" who have visited Russia for a few weeks. The controversy between Russian geneticists and the "environmentalists" has been published—in the Marxian quarterly *Science and Society* in 1940. In 1945 the leader of the new school of "genetics," Lysenko, permitted the translation of his book *Heredity and its Variability*. More recently, Hudson and Richens, of England, have published a very comprehensive survey of *The New Genetics in the Soviet Union*, with quotations from the original Russian literature. In the field of genetics we can, therefore, let the Russians speak for themselves.

The geneticists of the world had only the highest praise for the work of their Russian colleagues during the years from 1925 to 1939. The leading Soviet geneticist, Nicoli Vavilov, was a member of the Soviet Academy of Sciences, President of the Lenin Academy of Agricultural Sciences, and Director of the Institute of Applied Botany. He was a foreign member of the Royal Society of London and was elected President of the International Genetics Congress held in Edinburgh in 1939, although he was not permitted to attend this congress. In 1943 he was considered for membership as a foreign associate in our own National Academy of Sciences, but by that time he had been liquidated. Other Soviet geneticists of international reputation included Kar-

pechenko, Lewitsky, Navaschin, Dubinin, and Serebrovski. Dobzhansky came to the United States, and Timofeeff-Ressavsky went to Berlin, but they were trained in Russia. These and many other Russian scientists are held in very high regard by American geneticists for their abilty, their enthusiasm, and their friendliness. They have done much for the progress of genetics and for international cooperation in science.

Opposition to genetics in Russia began to develop in 1935 under the leadership of T. D. Lysenko. By 1940 Lysenko had replaced Vavilov as Director of the Genetics Institute of the Academy of Sciences and the Institute of Applied Botany. The Academy of Sciences in Russia directs all scientific activities in that country. Today genetics is almost completely suppressed in the Soviet Union and is taught at only one university—the University of Moscow. Even in 1939 the People's Commissar of Agriculture, Benediktov, recommended that all experiment stations were to accept Lysenko's theoretical views and apply his methods in seed production and breeding work.

The suppression of genetics and the development of Lysenko's power cannot be understood without considering the psychological and historical factors in Soviet history. Hudson and Richens have presented the psychological and political background that has led to the change and have shown how political philosophy has been used to control the science of genetics. They have read the original works of the Lysenko school and also the works of Marx, Engels, and Lenin, upon which much of the controversy is based.

All Russian scientists must subscribe to the doctrine of dialectical materialism, the philosophy of strife formulated by Marx and Engels and elaborated by Lenin. Stalin, in his writings, has indicated the attitude of mind that a scientist should show toward the philosophy of dialectical materialism and the proper fields of inquiry for a Marxian scientist. The essential ideas of this doctrine are;

1. Everything is material.
2. Matter is eternal but is always changing.
3. Matter is composed of opposing elements whose interaction is the cause of change.

The doctrine of dialectical materialism was made official by the Soviet government after the October revolution, but it had little impact on genetics for more than a decade. At the All Union Conference on Planning of Genetics and Selection in 1932, a resolution was passed that plant breeding and genetics were to conform with dialectical materialism, but apparently this resolution was taken no more seriously than is a politician's promise in this country.

In 1936, at the Lenin Academy of Agricultural Sciences, Lysenko opened his attack on genetics on the ground that it was inconsistent with dialectical materialism. He was answered by Vavilov, H. J. Muller (now returned to this country), Dubinin, Serebrovski, Navaschin, and Karpechenko. Lysenko was supported by a host of speakers—all completely unknown so far as international reputation is concerned. However, Lysenko and Prezent made a great impression on the nonscientific members of the Congress. Vavilov, as head of the Institute of Plant Industry, was attacked vigorously. He was accused of having failed to apply genetics to practical problems, of introducing worthless foreign varieties into Russia, of friendliness for genetical ideas emanating from fascist Germany and capitalistic England and the United States, and of being unfriendly to the theories of Michurin and Lysenko.

In 1939 another conference was held in Moscow. At this meeting genetics was attacked on the grounds that it was a foreign capitalistic science and inconsistent with Marxian philosophy. Much of this con-

troversy was published in *Science and Society*. The following year Lysenko replaced Vavilov as head of the plant-breeding work in Russia. Vavilov lost not only his job but also his life. How he died only the Russians know, and they won't tell. Since Vavilov's liquidation there has been no reference to his work in the Russian literature.

The conflict between science and political philosophy in the Soviet Union is shown by arguments used by Lysenko in his attacks on genetics. First, there is the appeal to authority; and dialectical materialism is the basis for all procedures both in political activities and in science. The authorities in genetics are Darwin, Timirjazev, Michurin, Burbank, and Lysenko, and the opinions of these authorities must be accepted.

Many concepts are classed as heresies, including metaphysics, capitalism, fascism, and theism. Genetics has been attacked by the Lysenko school on the grounds that it is a capitalistic science and was founded by a theist. The fact that Mendel was a priest has been used to discredit his ideas of heredity. The laws of probability are considered metaphysical and are discredited in their application to Mendelian segregation. According to Lysenko, "We biologists do not want to submit to blind chance, even though this chance is mathematically admissible. We maintain that biological regularities do not resemble mathematical laws."

The appeal to authority, the infallibility of chosen leaders, the denunciation of opposing ideas as heresies, and the alogical premises are all strangely reminiscent of certain brands of Christian doctrine.

WHO is this man Lysenko who is now in charge of all plant-breeding and agronomic work in the Soviet Union? He is not only the Director of the Genetics Institute of the Soviet Academy but is Vice-chairman of the Supreme Soviet and has received the Order of Lenin and other honors. His international reputation dates from 1932 when he announced his theory of "vernalization," an old method of altering the growth cycle of plants discovered in this country in 1857. This practice is popular in Russia but has been found to be of no value in increasing crop yield in other parts of the world.

Lysenko maintains that pure lines inevitably degenerate (matter always changes), that mutations can be induced by environment, that characters that are best adapted to the environment are dominant, that crosses within a pure line restore vigor, that there is no regular segregation of characters in hybrids, and that crosses between true breeding parents may produce a heterogeneous F_1. It is true that some of these events do occur, but they are entirely in accord with orthodox genetics and are the exceptions which prove the rule.

According to Lysenko, the chromosomes have nothing to do with heredity. The hereditary characters are carried by the nutritive sap, and the nutritive sap can be modified by nutrition or by other environmental factors. Good nutrition will improve the nutritive sap and thereby improve the variety or the race. Dolgushin even claims that if a plant is divided and one half grown in good soil, the other in poor soil, and then crossed, the progeny will show hybrid vigor —owing, of course, to the reaction of opposite types of nuclear sap.

He also claims that a plant can be changed by graft "hybridization." One species or variety grafted on another is nourished by the sap of the root stock and its heredity is thereby changed. This idea of Michurin's is discredited by hundreds of years of horticultural experience, although there is a remote possibility that in certain extreme combinations there may be an induced genetic interaction.

Liberal use of the popular press and offi-

cial support has enabled Lysenko to dominate all plant-breeding work in Russia in spite of his scientific illiteracy. His ideas are widely accepted by almost all farm workers, experiment station technicians, and by many plant breeders in Russia. There are, of course, many Soviet scientists who do not accept Lysenko's ideas, and a few are openly critical. However, according to Hudson and Richens, "Some sort of recognition of the value of dialectical materialism in scientific work and a tendency to exalt the work of Darwin, Michurin, and Timirjazev appears to characterize almost all Russian genetical publications" irrespective of the attitude taken toward Lysenko's theories.

Even though most farm workers agronomists, and political leaders subscribe to Lysenko's doctrines, some good work is being done in genetics in the Soviet Union. Dubinin and his associates are doing excellent work on Drosophila genetics at the University of Moscow. They are criticized by the Lysenkoites on the ground that they are working with lethal factors—"the flies die, but the scientists do not pay the penalty." Zhebrak and Tsitsin are producing new species of wheat by species hybridization followed by chromosome doubling. This work is done on an enormous scale, and Zhebrak and his associates have produced nearly a hundred new species during the past ten years. However, most of this work in plant genetics is simply the application of principles established twenty years ago.

There is evidence also that Lysenko's power is waning. As Hudson and Richens point out, the fact that most geneticists pay tribute to dialectical materialism and the canonized saints of science is not proof that they accept Lysenko's ideas. In fact, at least one Russian geneticist, Zhebrak, although insisting that a knowledge of dialectical materialism is essential for scientific work, is openly critical of Lysenko's ideas. The older geneticists undoubtedly still believe in Mendelism and the chromosal mechanism of inheritance. The Russians are realists, and the political leaders as well as the farmers must eventually discover that Lysenko's claims have no basis in fact.

The utilization of political philosophy to alter scientific programs is not so evident in other fields of Soviet science, but there is evidence in fields related to genetics. According to H. H. Newman, of The University of Chicago, the work on identical twins at the Maxim Gorky Institute was suddenly terminated in 1939, and nothing was heard of the disposition of the psychologists in charge of the work. Excellent work was in progress with identical twins to determine the relative roles of inheritance and environment. Perhaps the results were not in accord with political doctrine. Nikolai Koltzov was also denounced by the Soviet Academy of Sciences for his belief in eugenics, and mental tests of school children were prohibited.

The fact that genetics and allied sciences seem to have suffered most may be attributed to wishful thinking, not only by the Soviet officials but by the general public. If human development were based entirely upon environmental factors, it would be possible to eliminate the morons and defectives who burden society simply by providing a proper environment. If, however, heredity plays a part in mental and physical deficiencies, the problem is much more difficult. Furthermore, the genetic concept is not readily accepted by a gullible public, which prefers to indulge in wishful thinking.

The astronomers also have paid tribute to dialectical materialism. The Astronomical Division of the Academy of Sciences passed a resolution declaring that "modern bourgeois cosmogony is in a state of deep ideological confusion resulting from its refusal to accept the only true dialectic-

materialistic concept, namely, the infinity of the universe with respect to space as well as time," and the belief in relativity was branded as counter-revolutionary. In Germany the belief in the theory of relativity was banned on other, but equally fallacious, grounds.

The doctrine of dialectical materialism seems to permeate all fields of science. According to Waldemar Kaempffert, articles in Soviet journals have appeared under such titles as "Marxism and Surgery," "The Dialectics of Graded Steel," and "Dialectics of the Internal Combustion Engine." There is, however, no evidence that these tributes to political dogma mean any more to most Soviet scientists than do the professions of democracy and Christianity in countries that are neither democratic nor Christian.

In the words of Hudson and Richens,

> The difficulty is to discover in what way dialectical materialism can be used profitably in scientific work. If Lysenko's ideas are accepted, only a very few scientific concepts owe anything to dialectical materialism, and up to the present no attempt to recast science on a Marxian basis has gained any general acceptance.

The secret of the progress of science and technology in the Soviet Union cannot be attributed to Marxian philosophy. What is the basis for its relative progress? The most important factor is the very liberal support given scientific work by the Soviet government. Before the war Russia was spending a larger proportion of her budget for scientific research than any other nation. According to Lauterbach in his book *These Are the Russians*, Tsitsin had an annual budget equivalent to many millions of dollars for his institute for crop production on poor land. This sounds fantastic, yet Vavilov once told an American geneticist who wished to work in Russia that he could give him a million acres of land and hundreds of assistants for his work, but admitted that he could not obtain even a single room for living quarters for a visiting scientist.

Science does receive liberal support in the Soviet Union, particularly the application of science to practical problems. Yet if a man like Lysenko can dominate and control most of the plant-breeding and crop improvement programs in the entire Soviet Union, there is always the chance that some demagogue will do the same thing in some other field of science. In addition to liberal support the Soviet government exercises a considerable degree of control in coordination and direction of scientific research under the direction of the Soviet Academy of Sciences. According to Kapitza, "The Academy is called upon to direct all our science ideologically from top to bottom," and "each of its separate institutes must pursue the same policy." Such a program can effect technological progress, but this policy may result in serious consequences, as is evident in the science of genetics in Russia today. It seems wiser to follow the advice of Frank B. Jewett, former President of our own National Academy, who maintains that "fundamental science can be aided—it cannot be directed."

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THE THEORY OF RELATIVITY AND THE ATOMIC BOMB

By S. H. GOULD

Professor Gould (Ph.D., Yale, 1933) is a rare combination of classical scholar and mathematician. He is moving from his position in classics at Victoria College, University of Toronto, to the Department of Mathematics at Purdue University. One of his hobbies was the learning of foreign languages; another, the writing of articles on the history of science. During the war he was a Research Officer in the National Research Council of Canada.

THROUGH its effect on our ideas of space and time, the theory of relativity has held the attention of the public for 30 years. Interest in it has been intensified in recent months by its connection with the atomic bomb, indicated in the equation $E=mc^2$, "energy equals mass times the square of the speed of light." A discussion of the theory as a whole will make clear not only its practical application to the bomb but the nature of its wider influence on present-day thought.

The theory of relativity was originally published in two parts, the special theory in 1905, arising from an experimental dilemma and dealing only with observers in uniform motion, and the general theory in 1915, which attacks the more fundamental problem of taking into account the measurements of all imaginable observers.

The particular dilemma leading to the special theory was an observed disagreement with one of the basic principles of Newton's *Principia Mathematica*, published in 1687. The principle is to the effect that velocities are to be added; for example, if a freight train is passing us at 30 miles an hour and a trainman is walking along it at 3 miles, then he is passing us, according to Newton, at 33 miles an hour. Such a statement appears obviously correct, yet we shall find that the experimental evidence against it is conclusive.

In 1851 the French physicist Fizeau, in comparing the passage of light through a motionless liquid with its passage through the same liquid in rapid flow, found that some but not all of the velocity of the liquid was imparted to the light. So the principle of addition of velocities received its first blow.

Then, in 1881, another experiment, performed in a dark cellar in Cleveland by the American physicist Michelson, produced an even more startling result. The earth, in its yearly journey around the sun, is moving at the rate of 18 miles a second. Michelson sent a ray of light across his cellar in the direction of this motion, and another ray at right angles to it. Each ray was reflected from the same distance back to the starting point, and the question arose: Did they arrive there at the same time? Michelson was confident that one ray would arrive later than the other. His argument can be understood as follows: If a swimmer, representing the first ray of light, swims a certain distance downstream and back, the return journey against the stream will take a longer time than the downstream journey. So the stream will be working against him for a longer period than for him and will hinder him more than it will help him. Thus he will take a greater time for his twofold journey than the man who swims the same distance straight across the current and back. Michelson was certain that he could detect as little as a one-hundredth part of the expected difference. Yet, when he made the experiment, there was no difference at all; the two rays of light came back at exactly the same time. No additional velocity had been imparted by the motion

of the earth to light traveling through the air of his cellar.

These and other observations lead to the following result. For motions of moderate speed, like that of a train, Newton's law for the addition of velocities departs so little from the truth that with present-day instruments the discrepancy cannot be detected. But for very great velocities, such as the various speeds of light through various liquids, only part of the additional velocity can be communicated; while to the greatest known velocity, that of light through air or, better, through a vacuum, nothing whatever can be added. So this latter velocity, which is equal to 30 billion centimeters a second, appears to be a sort of universal constant, for which reason it is usually denoted by the letter c.

The new principle of invariance of the speed of light is in direct contradiction to the older, apparently self-evident, principle of the addition of velocities. So we may well expect startling consequences. In order to investigate them, we shall suppose that we are standing about midway on the platform of a railway station and that a long freight train is passing us in uniform motion, that is, in a straight line at constant speed. Einstein, in his first paper on relativity, with the title *Electrodynamics of Bodies in Motion*, used a conductor of electricity instead of the platform, and a moving magnet instead of the train, and showed that his theory gave the first satisfactory account of Maxwell's equations, which describe the interrelation of electricity and magnetism. But in his popular books he uses trains, even though he is referring to effects which with present-day instruments are not discernible for motions of a train. In writing these books he was in much the same position as the early Greek scientists who wished to convince their contemporaries that the earth is not flat. In 250 B.C. Eratosthenes knew very well that the earth is a sphere, and his calculation of its circumference was right within 50 miles. But his arguments were based on astronomical observations beyond the comprehension of the man in the street, who therefore remained unenlightened by statements like: "The surface of the ocean on a windless day partakes of the curvature of the earth and so is level but not flat, and its curvature, though we Greeks cannot detect it with the instruments of our day, can easily be calculated." But after 1521, when Magellan circumnavigated the globe, these ideas became familiar to everyone, and with modern instruments the curvature of the surface of the ocean can easily be measured by the practical navigator.

Similarly, in modern times, the theory of relativity, on the basis of astronomical and other arguments, some of which we have already examined, asserts that under certain conditions the readings of two clocks, which are in agreement by Newtonian theory, will in fact differ from each other by as much as a billionth of a second. The difference cannot be measured today, at least not with conventional clocks. What we must therefore do is to imagine our human eyesight as considerably sharper, so that if a theoretical discussion shows that two clocks differ by a billionth of a second, the difference will be as apparent to us when we look at the clocks as though it amounted to five minutes or more.

We shall now suppose that when the train is about halfway past us, it is struck by two bolts of lightning, one at the engine and the other at the caboose, and that the bolts leave permanent scars on the train and on the adjacent parts of the platform. The question arises: Were the bolts simultaneous? We set about answering it in the following way. First, we note whether they appeared to us to be simultaneous, that is, whether their flashes of light reached our recording instruments at the same time; and we shall suppose that they did. We now measure the distance along

the platform to each of the scars. If one of these distances should turn out to be somewhat greater than the other, we would say that the more distant event had happened first, since its light would take longer to reach us. But let us suppose that the two distances prove to be exactly the same. Then we would say that the two events, though separated from each other in space, were simultaneous, that is, were together in time.

Let us now turn our attention to the train, and suppose that at the moment of the striking of the bolts, a group of people is standing on top of a boxcar just opposite our position on the platform. Among them, also, the question arises whether the bolts were simultaneous, and in order to answer it they make the same measurements as we did. They find, by measuring along the top of the train, that they too were exactly midway between the bolts. But do they find that the two flashes of light reach them simultaneously?

From our position in the middle of the platform, let us watch the progress of the ray of light which starts along the train from the caboose. We now know, in contradiction to traditional ideas, that the velocity of the caboose will not be imparted to this ray, which will thus remain side by side with the ray along the platform. When the platform ray reaches our instruments, the train ray will therefore reach that point of the train which is now directly opposite to us. But the group of people is no longer there. They have been carried forward to a point some distance ahead, namely, the distance traveled in the meantime by the train. This distance is easily calculated; for ordinary trains, it is about a hundred-millionth of an inch and is, of course, plainly visible to our superior eyesight. So the light from the caboose has not yet reached the observers on the train. On the other hand, the front platform ray, coming to us along the platform beside the front half of the train, is also, just at this moment, reaching our instruments, and the front train ray, keeping pace with the ray along the platform, has already passed the train observers in their slightly advanced position. Since the light from the front has already passed them and the light from the rear has not yet reached them, they will unhesitatingly say that the bolt at the engine occurred before the bolt at the caboose. Yet we said they were simultaneous. Which of us is right?

Einstein's answer is that the question is incomplete and therefore meaningless. To ask whether two events are simultaneous is to ask a meaningful question only if they occur at the same place or if they are observed by people who are not in motion with respect to one another. If the events take place at a distance from each other, they may be simultaneous for some observers, and, if they are, there will be other observers for whom they are not simultaneous. Newton's *Principia* assumes that if two events are simultaneous for any one observer, they are simultaneous for all observers. Einstein shows, as we have just seen, that this is not the case. A property of any set of events which is the same for all observers is called an *invariant* or *absolute* property, and properties which are different for different observers are called *relative*. So for Newton simultaneity is absolute and for Einstein it is relative.

Let us now suppose that at each of the two places struck by the bolts there is an observer on the train and an observer on the platform and that each of the four observers is equipped with a clock. Since the two train clocks are not in motion relative to each other, we may assume that they are keeping time together, and similarly for the two platform clocks. Again, since the two rear clocks were on the same spot, we may take it that they showed the same time, say, exactly noon, when the rear bolt

struck. But what about the time of the striking of the front bolt? For platform observers the bolts are simultaneous, so that the front platform clock will show exactly noon. But for train observers the front bolt occurred a little before the rear bolt, so that the front train clock will indicate that it struck a little earlier than noon, and the front train observer will consider that the front platform clock is fast. This result does not mean that either clock is wrong; for it is a familiar principle, first established by Galileo about 1600, that as long as the train continues to move uniformly, the passengers cannot detect its motion by anything that happens in it, so that it provides just as good a laboratory, or frame of reference, as the platform. The conclusion we must reach is simply that measurement of time is relative.

From this result it follows directly that measurement of space is also relative. Consider the question: Is the train exactly as long as the platform? Platform observers will say: "Yes, the front of the train reached the front of the platform just as the rear of the train reached the rear of the platform, exactly at noon. So the two are exactly equal in length." But train observers will say: "No. The front of the train reached the front of the platform before noon, at which time the rear of the train had not yet reached the rear of the platform. So the train is longer than the platform." Thus measurement of space, like measurement of time, depends on the relative motion of the observer, and since motion itself involves both space and time, it is clear that these two entities, which up to 1905 had always been treated as distinct, are in fact inseparably connected.

WE MAY now return to the dilemma from which we began. It arose from Fizeau's experiment with the velocity of light through liquids in rapid flow. From the fact that velocities are not additive, we must conclude that if a train is passing us at 30 miles an hour and a trainman is walking along it at 3 miles, then he is passing us, not at 33 miles an hour, but at a slightly lower speed. For this somewhat disturbing result, we now have a simple explanation. If the trainman began at noon at the back of a train which for him was 3 miles long, and if he therefore took one hour of train time to walk its length, then he arrived at the front end at one o'clock by train time, but slightly after one o'clock by platform time. Also, by platform standards, the train is slightly less than 3 miles long. So, for both these reasons, his total speed as measured from the platform is somewhat less than 33 miles an hour, and our original dilemma is resolved.

It is therefore meaningless to ask: "At what time and place did an event occur?" We must ask: "At what time and place for what observer?" To ask simply whether one event is earlier than another is somewhat like asking whether one sunset is more beautiful than another. It depends on the observer. Nevertheless, there is a fundamental difference between the two questions. The beauty of sunsets does not admit mathematical calculation. But if we know the time and place of an event for one set of observers we can easily calculate its time and place for the others. We can make a transformation of the one time and place into the other. In ancient days, the Greek astronomer Ptolemy observed the motion of the planets as seen from the earth. Then Copernicus made a mathematical transformation which expressed their motion as it would be seen from the sun, where it appears in a much simpler form. Copernicus dealt separately with time and space; but in Einstein's transformation, named after the Dutch physicist Lorentz, time and space depend on relative velocity and therefore are inseparable. For any pair of events, occurring in the external world, observers

will find two numbers, representing the distance between them in space and their difference in time. In the older theory, these numbers are the same for observers on the train and on the platform, but we are now aware that each of them, taken by itself, is different for the two sets of observers, and only a certain combination, determined by the invariance of the speed of light, remains the same. This single number, formed by combination of the numbers representing distance in space and difference in time, is left unchanged by the Lorentz transformation and is called the *interval* between the two events.

The Lorentz transformation contains nothing more complicated than a single square root sign, and since it leaves invariant the speed of light, c, it must involve under its root sign the quantity c^2, which appears in the equation $E=mc^2$ of the theory of the atomic bomb. To understand this equation, let us imagine that we have before us a certain quantity of matter, say, a teaspoonful of water. The letter m is simply the number of grams of water—in this case a little more than five. The c^2 is already familiar to us; in the ordinary units of measurement, it is the number 30 billion multiplied by 30 billion, equal to 900 quintillion. The letter E, which we must now discuss somewhat further, indicates the amount of energy that would be released if we could completely annihilate the water.

The Greek word *energy* means ability to do work, such as accelerating an automobile or heating a house. The energy to do it may be available in different forms, such as energy of motion, potential energy, or energy of radiation. An object in rapid motion possesses a great deal of energy of motion, which can easily be made to do work; for example, it will accelerate the motion of any other object with which it comes in contact. A stone poised at the edge of a high cliff has potential energy, which can be converted into energy of motion by allowing the stone to fall. In its downward course, its potential energy will decrease with the increase of its energy of motion, the sum of the two remaining constant, in illustration of the fundamental principle of conservation of energy. Energy of radiation is in the form of electromagnetic waves which pass with the speed of light through a vacuum, say, between the sun and the earth, in accordance with Maxwell's equations. The energy transferred in these waves will be of different kinds, depending on their length. Radiant heat is transmitted through a vacuum in comparatively long waves and raises the temperature of any obstacle it encounters. Light is transmitted in somewhat shorter waves; radiation in very short waves produces X-rays, and in still shorter, the similar but even more penetrating gamma rays.

The unit of energy is the *erg*, which is equal to twice the energy of motion of a gram of matter moving at the rate of one centimeter per second. The equation $E=mc^2$ states that if matter can be annihilated, the number of ergs of energy released is 900 quintillion times the number of grams of matter destroyed, so that a teaspoonful of water would produce about 5 sextillion ergs, enough to heat an average residence for 4,000 years.

The ideas that first suggested to Einstein the formula $E=mc^2$ are very simple. We have seen that the faster an object is moving the more difficulty we have in imparting to it any additional velocity. But this difficulty is also characteristic of massive objects, which require more force to speed them up. Greater velocity or, in other words, greater energy is thus equivalent to greater mass, and the fact that addition of velocity depends on the Lorentz transformation, containing in a simple way the number c^2, was sufficient to indicate that the relation between increase of mass and increase of energy should take the simple form $E=mc^2$.

We have spoken of the annihilation of

mass, but what actually happens is its transformation into energy. Matter and energy, the two cornerstones of earlier physics, are now combined into one. A ray of light is considered as possessing mass, though in a fantastically rarefied form; and, conversely, a massive object, like a stone, results from a fantastic concentration of energy to form the nucleus of an atom. The nucleus of uranium-235, the element used in the atomic bomb, contains 235 elementary particles, called neutrons or protons according to whether or not they are electrically neutral. When the nucleus is struck by a free neutron from some external source, it splits into two fragments and releases three or more free neutrons. The total weight of the products is somewhat less than the weight of the particles originally in collision, and the difference is made good by release of energy according to the formula $E=mc^2$. If the collision takes place within a fairly small piece of uranium, the neutrons thus set free will probably escape into the atmosphere, which in any case contains free neutrons in considerable numbers. But if the collision occurs in the interior of a larger piece of uranium, the liberated neutrons will not all escape but will set up a chain reaction with explosive effects.

The method of detonating the atomic bomb is therefore as follows: A piece of uranium, below the critical size but greater than half of it, is set up as a target. Then, by a time-mechanism, a similar piece is projected against it like a bullet. The larger piece, formed by their union, is above the critical size and explodes automatically. The energy thereby released is chiefly in three forms: energy of motion in the fragments of fission, which fly apart at great speed; heat, intense enough to vaporize a steel tower; and energy of radiation in the form of gamma rays which destroy living tissue over the area of a large city.

Returning to the discussion of relativity, we note that our results up to now have been based on the two principles characteristic of the special theory, that the speed of light is invariant and that as long as the train continues to move uniformly it provides as good a laboratory in every way as the platform. If one experimenter sets a billiard ball at rest or rolling uniformly on the platform, and another makes the same experiment on the roof of the train, each of them will be led by observation of his ball to Newton's first law of motion, that a particle of matter continues indefinitely in its state of rest or uniform motion as long as it remains free of external forces. But if the train increases its speed or goes around a curve, the ball on its roof will roll suddenly backwards or to the outside of the curve. The train observer will have difficulty in finding any simple law for its motion and will conclude that the train provides a less suitable frame of reference than the platform.

But the platform itself is not altogether satisfactory, because similar effects are produced on it by the rotation of the earth. These effects may be illustrated by the motion of the long, south-flowing rivers of Russia like the Dnieper, the Volga, and the Don. They tend to have a rocky western bank, whereas the eastern bank is smooth, the reason being that as they flow into regions nearer the equator they are carried more rapidly eastward by the rotation of the earth, so that their water is thrown by so-called inertial or centrifugal force against the western bank, which is thus worn away continually until some rocky obstruction is reached. Effects of this sort were assigned by Newton to rotation of the earth in a supposed "absolute space," everywhere homogeneous and at rest and extending infinitely in every direction. But Newton's own memoranda indicate that he was dissatisfied with this explanation, which sins against at least three fundamental principles of science. In the first place, absolute space cannot be measured in any way and has no discoverable property except the one for which it was

introduced, that of exerting "force" on matter supposedly in rotation or accelerated motion. Second, changes in a gravitational field arising from changes in the massive body itself are considered in the Newtonian theory as taking place instantaneously throughout the whole universe; that is, as being propagated with infinite velocity, a conception totally at variance with theory and observation in any branch of science. And, third, the explanation neglects one of the most accurately observed phenomena of nature, namely, that when air resistance is removed all material bodies fall with exactly the same acceleration; or, in other words, that the effects of gravitation are identical with the effects of acceleration. When a rising elevator is accelerated, its passengers will note that objects let go from the hand reach the floor more quickly than before, a result which may equally well be ascribed to an increase in the force of gravity in the elevator, or to its motion with respect to the earth. Newtonian theory admits only the second of these two explanations, but observers in the elevator will be dissatisfied with a distinction which they cannot support by any conceivable experiment.

For these and other reasons, the concept of absolute space was abandoned altogether by Einstein, who assigns the motion of the Russian rivers, not to any absolute rotation of the earth, but to rotation relative to all other matter in the universe, and in particular to the immense masses of the stars. Centrifugal effects are thereby related to the gravitational fields of massive bodies, which produce in their neighborhood, not a force of gravity, but a modification of space and time, introducing phenomena which, as we shall see, are inconsistent with the geometry of Euclid.

If now, compelled in this way to abandon the idea that gravitation is a force, we seek an instance of motion undisturbed by any force, we shall find it, not in the movement of the billiard ball supported by pressure from the platform, but in the journey of a planet round the sun. The more distant the planet, the less sharp is the curve of its orbit, which thus more and more nearly resembles a straight line but is never exactly straigth. In special relativity we considered observers as being in a preferred position if their observations indicated that freely moving objects follow straight lines. We now see that such a motion would take place only at an infinite distance from all matter.

So we give up our search for a preferred observer and seek to state a law of motion valid for all observers in every imaginable position and state of motion. Any physical observation depends partly on the observer and partly on the external world, and it is the task of general relativity to describe exactly that part common to all observers. The planet Mercury would appear motionless to an inhabitant stationed on its surface; from the earth it seems to move in a complicated curve described by Ptolemy, and from the sun in a simple ellipse. How can we state a law of gravitation which, unlike Newton's theory, shall avoid any reference to absolute space and yet be exactly the same for all observers?

To accomplish this task, it will be necessary to generalize Newton's first law of motion to read: the paths of freely moving bodies are not necessarily straight lines, but are *geodesics;* that is, lines of shortest distance or interval between two points or events. On a flat surface, where Euclidean geometry is valid, the geodesics are straight lines; on the surface of the ocean they are arcs of a great circle; and on a rugged mountain they may take very complicated shapes. If space in the neighborhood of the sun were Euclidean and independent of time, the planetary orbits would thus be straight lines; but the presence of the sun produces a disagreement with Euclidean geometry such that the orbits take a curvilinear form. At a

very great distance from matter, space is approximately Euclidean and is connected with time in the manner of special relativity. In the neighborhood of matter, it retains, as we shall see, a certain qualitative similarity to Euclideanism.

In any case, it is clear that if we wish to pay equal respect to the measurements of all imaginable observers, we must make some study of non-Euclidean geometry. For we have found that two observers in the uniform motion of the special theory are unable to agree on the lengths of train and platform; and in the general theory, in which their relative motion may be constantly changing in speed and direction, these disagreements will take place to a different extent in different directions, so that at least one of the two observers will find that the sides of a triangle do not satisfy all the theorems of Euclidean geometry.

Euclid's geometry originated in the practical world, in the problems of the surveyor. He begins with a set of axioms, statements which he cannot prove but regards as forming a satisfactory basis for further inquiry. Most of them, such as "things which are equal to the same thing are equal to each other," seem unavoidable; but one of the axioms is different from the others. It is essentially to the effect that through a given point there is one straight line parallel to a given straight line. By saying that the two lines in question will not have a point in common no matter how far they are produced, this axiom makes a negative pronouncement referring to immense distances and does not seem to recommend itself with quite the same force as the others. It was introduced by Euclid in a noticeably hesitant way; he seems to feel uncertain whether or not it is suitably chosen, but to be sure at least that, once it is accepted, it implies the theorems familiar today to the student in high school. Especially important among them is the theorem of Pythagoras, that the square on the hypotenuse of a right-angled triangle is equal to the sum of the squares on the other two sides; or, to take the special case with which Pythagoras began, if the sides are three and four, then the hypotenuse is five.

So the geometry of Euclid is based upon certain axioms of a logical nature which few would be inclined to reject and upon at least one other axiom suggested solely by observation of the external world. Modern mathematicians, among them Riemann in 1854, have asked themselves what would happen, quite apart from the external world, if they were simply to omit this special, obtrusive axiom. What sort of geometry could they build up? Would the theorem of Pythagoras remain unchanged?

Let us suppose, then, in a purely theoretical way, that no pair of straight lines is ever parallel. It follows, by reasoning analogous to Euclid's, that the hypotenuse of a right-angled triangle is too short to satisfy Pythagoras. But we go ahead undeterred and by logic alone construct a geometry in which some of Euclid's theorems can still be proved and some are changed.

So far we have been following Riemann as a pure mathematician. But he was also a physicist, interested in the practical question whether careful measurements, such as had already been made by his older compatriot Gauss, would lend support to his new geometry. Until recent times, when the motion of the planet Mercury was brought to bear on the question, these measurements remained without positive result and even aroused considerable scorn among certain philosophers, who argued that if measurements should run counter to the theorem of Pythagoras they would prove only that the instruments, or perhaps the experimenters, were warped.

In considering the special theory we found it desirable to equip ourselves with miraculous eyesight. The situation is similar in the present case. From the observable motion of the planet Mercury, and for other reasons,

it is possible to deduce certain theoretical consequences for ordinary measurements here on earth, and we shall simply suppose that we possess instruments, or eyesight, of sufficient delicacy to detect the minute distances involved.

Let us ask someone to construct for us a pair of straight lines which are parallel according to Euclidean geometry. How can we test them? We measure the distance between them at two different points to see whether they are approaching each other, and when we find that they are, we ask the Euclidean geometer: "Why do you think they are parallel?"

"Because it's proved in Euclid's geometry, on the basis of his famous axiom."

"Why did he introduce the axiom?"

"Well, he was a bit uncertain about it, but measurements of his day tended to support it."

"But we measure more accurately than he did?"

"Oh, yes, that I do admit, by any criterion."

"Then why do you reject our measurements in favor of his?"

At this, our Euclidean friend will brighten up, if he is like those who argued with Gauss, and say: "After all, you know, these accurate measurements have nothing to do with the case. Any rational discussion of geometry must be based not on a material, measurable line, but on a certain idea of the straight line which presents itself irresistibly, not to man's senses, but to his reason; and Euclid's axiom merely gives expression to one of the necessary properties of this line."

The relativist will agree that the straight lines under discussion are not evident to our senses, but will deny that we must accept Euclid's axiom as one of their properties in order to talk about them rationally. The deification of the axiom seems to be due simply to the fact that we live on a small planet. For it is a fundamental tenet of relativity that the rules of geometry at any point of space depend, as we shall see, on the nearby distribution of matter. On the surface of the sun, which is much larger than the earth, disagreement with Euclid's geometry would be evident even to our senses, and the stubborn objections to non-Euclidean geometry would never have been made.

Enough for the objections; let us turn to the subject. We have here a smooth, circular dining-room table. A billiard ball, placed at various points on its surface, shows no tendency to roll, so we conclude that the table is perfectly level and on it we draw a right-angled triangle, three feet on the one side and four feet on the other. Pythagoras says that the hypotenuse is five feet long. But when we measure it, we find it is shorter than that. What is the explanation?

The Euclidean geometer will say: "Oh, that's easy. Your surface is level, all right, but it isn't flat. Like the surface of the ocean, it partakes of the curvature of the earth. Suppose, instead, you take a large drum and by tightly stretching its membrane you remove this slight curvature. Then you'll have a truly flat surface, and I warrant you'll find that Pythagoras was right." So we try again, and find that the hypotenuse is still too short, though by a much smaller amount. The relativist says: "I expected this: you see, we're working in the gravitational field of the earth, so that in our particular part of the universe, geometry is nearly but not quite Euclidean."

For the older geometer this remark will raise the following question: If Euclidean geometry fails to hold on the surface of the earth because this surface is not flat but curved in a third dimension, would it be right to suppose analogously that Euclidean geometry fails to hold in our familiar three-dimensional space because this space is curved somehow in a sort of spatial fourth dimension? How can anyone visualize such a dimension or ever make a measurement in it?

In this respect the natural feeling is com-

pletely right. No one can visualize a fourth spatial dimension in any way, and there is no evidence that such a dimension exists. The conventional statement that ordinary space is curved in the neighborhood of the earth means only that it is non-Euclidean; that is, that when a ruler is laid down on the hypotenuse of our right-angled triangle, the end point of the hypotenuse does not coincide with the number five on the ruler—and surely that is no harder to visualize than that it should coincide.

The statement, on the other hand, that time is a fourth dimension is sensible enough, and easily understood. To describe an event we need four numbers, for example, 34, 5, 910, 28, which describe the crashing of an airplane into the Empire State Building on Thirty-fourth Street, at Fifth Avenue, New York, 910 feet above the ground, on July 28, three of the numbers referring to space and one to time. In this way, time was called a fourth dimension even in prerelativity days, and there is now all the more reason for this useful nomenclature since, as we have seen, measurement of time is inseparably connected with measurement of space.

The set of all events in the history of the universe, past, present and future, is then, for convenience, called a four-dimensional space, in which the interval between two events plays the role of distance between two points. An event is simply a coincidence in time and space, for example, of a ray of light from Mercury with the eyepiece of a telescope, and the motion of the planet represents a collection of events that is part of the larger collection of all events of the universe. To say that the planet follows a geodesic path means that the interval between nearby events, namely, the arrival of of the planet at one point and at another, is smaller, when calculated according to the geometry of the region, than if the planet took a different path or moved at a different speed. And to say that geometry is non-Euclidean in the neighborhood of a massive body like the sun or the earth means, first, that sufficiently accurate measurements will no longer support the theorem of Pythagoras and, second, that the connection between space and time is slightly altered, so that the speed of light is no longer constant, as in special relativity, but depends on the mass of the nearby disturbing body. It was a predicted change of this sort in the earthward passage of starlight close to the disturbing sun that was observed by British astronomers in Brazil during the solar eclipse of 1919.

AT THIS point the Euclidean geometer may ask a question which goes to the very root of the matter: If the theorem of Pythagoras is no longer true, what method can there be for calculating the distance between two points? Suppose we are engaged in an artillery duel in a city whose streets are regularly spaced. If the enemy is three blocks east and four blocks north, we know, if we accept Euclidean geometry, that for purposes of lobbing a shell our target is exactly five blocks away. Is there anything corresponding to this in Riemannian geometry?

Yes, there is. It is only necessary to combine the numbers *three* and *four* after multiplying them by certain factors which depend on one's position in the city. The same situation arises in the geometry of an ocean navigator. If he sails east by three degrees of longitude and north by four degrees of latitude, his distance from the starting point depends on whether he is near the equator, where a degree of longitude is equal to 70 miles, or near the North Pole, where it is very small. To calculate the distance in question he must combine his numbers *three* and *four* after multiplying them by factors which depend on his starting point.

The factors he must use are determined partly by the actual shape of the earth and partly by his arbitrary choice of a system of

reference. For most purposes, he will choose the ordinary lines of latitude and longitude, but often he may find it convenient to take some other system, with meridians running through the magnetic pole, or with a more complicated change which will alter his factors in a calculable way. The various sets of factors will be different for different systems of reference but will be alike in certain properties arising from the approximately spherical shape of the earth. Let us consider all imaginable observers, that is, all imaginable ways of drawing a system of latitude and longitude. Each system will have its own set of factors, and any one set can be calculated from any other. But the whole aggregate of sets of factors, each associated with its own system of reference, remains the same, no matter who makes the calculations. This aggregate, invariant for all observers, is called a *tensor*, the factors in the various systems being called its *components*. The tensor as a whole depends only on the shape of the earth, of which it thus gives an objective description, and one or another of its sets of components must be used by every navigator to calculate distance. It is therefore called the *fundamental tensor* of geometry on the surface of the earth. From it we can deduce any theorem of geometry valid on such a surface; for example, the non-Euclidean result, impossible on a flat surface, that no two geodesic lines are ever parallel, since all great circles intersect one another.

From the components of the fundamental tensor may be calculated other tensors, giving more explicit description of various properties of the earth's surface; for example, the components of the *curvature tensor* will indicate that the curvature of the earth is everywhere about the same, with a slight flattening at the poles. If the polar regions were altogether flat, a polar navigator would find that all the components of the curvature tensor in his system would be equal to zero, a result which he would express by saying that the tensor *vanishes* in these regions.

A question now arises which is of central importance: what happens to the components of a vanishing tensor when they are transformed to the system of reference used by some other navigator? Ordinarily, the components of a tensor will change; but what about the special case in which they are all equal to zero?

Transformation of components is the most important part of the theory of tensors. It may be compared to a kind of complicated multiplication, the value of the comparison lying in the special role played in ordinary multiplication by the number zero, which remains unchanged when multiplied by any number. If a gambler loses money at Monte Carlo, the number expressing the amount will be different according to whether the loss is in dollars, in pounds, or in francs, except in the special case that it is equal to zero, when it will be the same whether the gambler is American, English, or French. Similarly, if the components of the curvature tensor vanish in polar regions for any observer, they will vanish there for all observers. The vanishing of a tensor represents an absolute law of nature, and, conversely, every law of nature can be expressed as the vanishing of some tensor.

In the same way that navigators assign two numbers to every point on the two-dimensional surface of the earth, so an observer in space and time assigns four numbers to every event in the history of the universe. And just as the two numbers assigned by the navigator depend partly on his choice of latitude and longitude and partly on the shape of the earth, so the four numbers assigned by the observer in space and time depend partly on his own position and state of motion and partly on the nature of space and time in the region in which the event occurred. The factors by which difference in latitude and longitude must be mul-

tiplied to calculate distance between two points constitute the components, as we have seen, of a fundamental tensor which gives an objective description of geometry on the surface of the earth. Similarly, the factors by which an observer must multiply differences in time and space as observed by him in order to calculate interval between two events are the components of a fundamental tensor which gives an objective description of motion in any region of space and time.

As before, we may calculate the analogue of the curvature tensor, called in this case the Riemann-Christoffel tensor. The Latin word *tensor*, meaning that which measures tension or stretch, is borrowed from the theory of elasticity and may be considered as measuring distortion of a region or, in other words, disagreement with Euclideanism of measurements made in it. Just as the vanishing of the curvature tensor indicates that a region of the earth is flat, so the vanishing of the Riemann-Christoffel tensor indicates that a region of space and time is Euclidean, which means that for certain observers, in uniform motion in respect to one another, the geometry of Euclid is valid in the region, and time is connected with space in the manner of special relativity. An observer who is in accelerated motion relative to the others will notice non-Euclidean phenomena, which arise from the fact that, in making his observations in a frame of reference in which he himself is at rest, he is using a different set of components of the fundamental tensor. But when he calculates the corresponding set of components of the Riemann-Christoffel tensor, he too will find that they all vanish and will conclude that the non-Euclidean phenomena he notices are due, not to any inherent property of the region itself, but to his own state of motion.

These are exactly the results of our observers in special relativity and would therefore be valid, as we have seen, only at an infinite distance from matter. Thus the Riemann-Christoffel tensor will not actually vanish in any region, though its components in any frame of reference will become more and more nearly equal to zero at greater distances from matter. And, as we approach a massive body, the gravitational effect of its presence will be expressed by a growing distortion, or non-Euclideanism, of space and time proportional to the mass of the disturbing body but retaining a qualitative similarity to Euclideanism, a similarity which is described by the vanishing of the *Ricci tensor*, formed from the Riemann-Christoffel tensor by combination of certain components.

Our fundamental tensor for space and time must therefore satisfy the condition that the Riemann-Christoffel tensor, as calculated from it, will tend to vanish in regions remote from matter, while the Ricci tensor will vanish at every point not actually in the interior of a material object. Since the fundamental tensor depends solely on the distribution and state of motion of matter, which we have seen to be the same as energy, the vanishing of these derived tensors, taken together with the principle of conservation of energy, determines the fundamental tensor for space and time in the same way as the shape of the earth determines the fundamental tensor for geometry on its surface. And, conversely, just as the fundamental tensor for the earth's surface determines the theorems of geometry which are valid on it, so the fundamental tensor for space and time determines the theorems governing motion of material objects along geodesic lines. One such theorem is that, under conditions approximately realized in the neighborhood of the sun, the oval-shaped orbits of the revolving planets will themselves revolve, very slowly, about the sun. Thus, the direction of the longest axis of the orbit of Mercury will make one complete turn around the sun in about two

million years. This result, applied by Schwarzschild in 1916 to the observed motion of Mercury, provided a practical test in favor of the new ideas as opposed to the Newtonian theory of gravitation.

The actual phenomena noted in a gravitational field are due partly to the motion of the observer and partly to the nature of the field itself. In a freely falling airplane, the field of the earth disappears altogether, since an object let go from the hand will not fall any faster than the airplane itself and will appear suspended in mid-air. Yet the earth's field must have some absolute significance, since it will make itself apparent in one way or another to every observer. For example, to the aviator falling in the sky over New York, it is doubled in intensity when he measures the motion, relative to himself, of objects falling toward the earth from the opposite side, say, from the sky in China. The differences noted by different observers arise from the fact that each of them refers his observations to his own frame of reference and consequently uses a different set of components of the fundamental tensor. What is common to all observers is that when each of them uses his own set of components of the fundamental tensor in order to calculate the corresponding components of the Ricci tensor, he finds that all these latter vanish; and it is this result which gives expression, in a form the same for all imaginable observers, to the absolute quality of the connection between space and time in the gravitational field of the earth.

Certain consequences of the new theory are admittedly strange at first sight. Newton thought that space must be infinite in extent because he regarded it as everywhere homogeneous; but with our new principle there is nothing to prevent us from having a finite but unbounded universe, analogous in this respect to the surface of the earth. Since the nature of space depends on the distribution of matter, about which the astronomers are able to supply some information, it has been possible to estimate the circumference of such a universe, and recent conjectures have set it approximately equal to the distance traversed by a ray of light in one sextillion years. Similarly, with regard to time, we encounter the paradox that if two travelers start out together and arrive together but travel by different routes, their journeys will in general require different lengths of time.

Yet why should these results be considered strange? Since we measure distances with a material yardstick, it is reasonable to suppose that their properties depend on the distribution of matter and that a straight line, being defined by means of shortest distance, may therefore make a circuit of the universe and return eventually upon itself. Again, if time must be measured with a material clock, why should it not pass at different rates for travelers who put themselves in different positions relative to all other matter? Surely, from a philosophical point of view, we shall feel deep satisfaction with this unification of the three fundamental entities—space, time, and matter.

MAN, THE MYTH-MAKER

By READ BAIN

Professor Bain (Ph.D., Michigan, 1926) is head of the Department of Sociology at Miami University, Oxford, Ohio. He believes that the social sciences should be regarded as natural sciences and has devoted much of his writing and teaching to the promotion of this point of view. He was editor of the American Sociological Review and he also edited three volumes of the Social Science Research Council's Critiques of Research in the Social Sciences.

TO A considerable degree, the history of man is the history of his myths. Myths suggest primitive people and ancient civilizations, but careful observation shows many ancient myths are still believed and some new ones are being made. Some of the latter are more detrimental to human welfare than many ancient myths which are now only half-believed. This statement is meaningless unless myth-mindedness means more than old tales about hypothetical gods. Myth-making refers to the slow, unplanned development of thoughts, feelings, and actions that are inconsistent with the findings of natural science.

Myth-making and myth-thinking characterize all forms of social behavior based upon any variety of animism, occultism, oversimplification, and the treatment of words as things rather than as symbols. To regard words and propositions as entities, or absolutes, is to enter the misty mid-regions of Mythodemia. The difference between myth-thinking and reality-thinking is the difference between absolute-relative, dogmatic-tentative, fantasy-fact, sacred-secular, revelation-science. Myth is based upon wishful, hopeful, fearful, awful thinking in contrast to critical, rational, practical, probability thinking. Myth is emotive rather than informative, connotative rather than denotative. Nonmythic thinking is based on empirical observation aided by instruments and carefully defined concepts within clearly delimited fields of sensory experience. It produces logical but tentative conclusions that are modified by subsequent research, experience, and critical restatement. In short, the opposite of myth-making is science-making.

The myth emerges from the uncritical verbalization of hopes and fears. It flourishes by repetition and authoritarian tradition, is sustained by coercive control, and finally dies out when science and common sense demonstrate its absurdity and harmfulness. It seldom dies a decent and definitive death, however. In subtle forms it lingers on to confuse men's minds and confound their management of practical affairs. Nothing about it but doth suffer a sea change into something new and strange. Often the revised myth is more viable than the crude form from which it came.

In contrast, a scientific hypothesis survives as a verified fact or valid principle or dies a clean-cut and final death. The scientist does not try to preserve it by burning people at the stake, putting them in concentration camps, or branding them as un-American; he forgets about it and goes to work on something new. Not so with the myth. Its death is agony long drawn out, and its obsequies are obscene. Its adherents are addicts. They persecute critics when they are in power and whine that they are being persecuted when their myths are being attacked and are falling into disrepute.

For convenience all myths may be classified as sacred and secular. The first class refers to the gods and their dealings with man and the world; the second deals with

man's inept attempts to deal with himself and the world. This distinction is not clear-cut since all myths by definition are created and perpetuated by essentially similar modes of thought and action. The secular myth usually relies upon some subtle and rationalized form of the sacred myth for its sanction. Some ghostly verbal remnant of the sacred myth often is fused with the functioning secular myth.

The history of sacred myths illustrates how myth-mindedness persists in subtle forms after the cruder concepts have become untenable. Great Pan was dead by the time of Euripides and Aristophanes. Even a century earlier, educated Greeks like Thales, Heraclitus, and Xenophanes had reduced the gods to a figure of speech. Little is known of how the post-Periclean common people regarded the gods, but it seems safe to assume their beliefs and practices were not much affected by the ideas of the sophisticates. The gods remained a vital myth to the masses long after they had become a mere myth to the elite. Nor did the death of the gods destroy the mythic mode of thought among the intelligentsia. On this point the record is clear. The crude anthropomorphic myths merely suffered a word change into such subtleties as Fate, Form, First Cause, and the erudite mysticism of Pythagoras, Plato, and Plotinus —a mode of thought which still muddles the minds of millions. Witness the Pythagorean assertion of a great modern scientist that God is a Mathematician (maybe it was a joke or whimsey) and the feminized Platonic Realism of Mrs. Eddy (certainly not a joke). The revelation of Tin Pan Alley and the cinema that "wishing will make it so" is a modern vulgar version of this ancient obsession with word-magic.

In the first century a new sacred myth began to replace the moribund remnants of the Greco-Roman, Egyptian, and Near Eastern religions. The Christians soon decided all gods except their own were myths, and some men quickly saw the necessity for refining the concept of the Christian gods by eliminating their cruder human traits. Paul, the logic-chopper, began it, and John, the deifier of the Word, carried on. Eventually, the metaphysics of Plato, Aristotle, and Plotinus were fused with the Christian doctrines without any marked change in the mythic character of either the Greek or Hebraic components. In spite of this theological rationalization, the Christian pantheon remained crudely anthropomorphic for most followers of Jesus. God, The Devil, angels, imps, and semisupernatural saints were "real persons" for the masses, and the preaching of the pastors confirmed these folk beliefs instead of popularizing the theological subtleties. Otherwise sane and scholarly men like Jean Bodin and Jonathan Edwards believed in the actual existence of witches, sorcerers, and black magic. The cult of the Virgin is still as vital to millions of Christians as the cult of Venus was to the Romans—and performs somewhat the same function. It is less than a century since the church officially declared that the Mother as well as the Son was born untainted by original sin. Theologians had disputed the point for centuries.

With the rise of natural science, the sacred myths of Christianity began to suffer frontal attacks. This conflict was and is basically different from the theological quibbles and heretical movements that had plagued the church from Arius and Pelagius to Luther. These were merely variations on the basic theme of the Master Myth. For example, the Reformation produced no significant change in the Christian ideology. It had significant social implications, to be sure, but its immediate theological effect was a reversion to cruder and more anthropomorphic concepts than the well-rationalized and systematized myths of the great Catholic theologians. It was not until the

rise of modernism and the social gospel that Protestantism began to develop much metaphysical subtlety. With the rise of natural science, the very foundations and rationale of the Christian myth began to be questioned. Animistic supernaturalism found itself squarely confronted by scientific naturalism, and the sacred myth was forced to fight a defensive, and apparently losing, battle.

One result of this struggle was the development of more subtle versions of the sacred myths for the masses who had become increasingly literate—partly as a by-product of the Reformation—and therefore could not be isolated from the subversive influence of science. Millions still believe in some or all of the cruder sacred myths such as the literal inspiration and inerrancy of the Bible, miracles, the humanoid nature of the gods, personal immortality, and the "reality" of heaven and hell, and that the scientist is the Devil's most dangerous disciple, but they usually have plausible (at least, to them) rationalizations of their beliefs. The fundamentalist sees no contradiction in his use of the radio and printing press to condemn the scientist and natural science. He finds no difficulty in using both prayer and immune sera to combat contagious disease.

Increasing numbers of Western European Christians, however, have accepted such interpretations of the sacred myths that they have little difficulty in accepting all the findings of higher criticism and natural science. The modernist and "educated Christian" is rather short with his fundamentalist and pentecostal brethren, if not actually contemptuous of them, for their stubborn resistance to science and equally stubborn insistence upon a literal interpretation of the Bible. The modernist has made his peace with science largely by giving the Bible a poetic, "spiritual," analogical, and often illogical, interpretation; in short, by rationalization.

Many Christians escape from even these rationalized versions of the sacred myths. They no longer call themselves Christians, but many of them do not escape from the mythic mode of thought and feeling any more than did the Greeks when they replaced the gods by Fate and Form. Witness the millions of believers in astrology, numerology, fortunetelling, spiritualism, clairvoyance, mental telepathy, extrasensory perception, luck, charms, New Thought, yogism, hermeneutical mysteries, Rosicrucian mysticism, and fifty-seven other varieties of semisacred myths that deny the evidences of the senses and the findings of science.

So much for the sacred myth. It seems to be losing its dominance and eventually may almost disappear, but the mind of the myth-maker and myth-monger is fearful. When his myth begins to lose its vitality, he is thrown into confusion; he begins to cry out for a "return to reality;" we must trust our feelings and intuitions; we must reject science, logic, and common sense—"the wisdom of man is foolishness unto the Lord;" we must plead with the saints for miracles; we must accept the metaphysical absolutes of modern word-magicians, some of whom are famous professors in great universities.

It should be noted, however, that many who call themselves Christians are relatively free of myth-mindedness, at least in religion. They recognize that modern Christianity may be, and probably must be, if it is to survive, in complete harmony with the findings, methods, and point of view of natural science; that there is no place for miracles and supernaturalism in a modern functional religion; that religion is primarily a system of supreme values that are based upon natural science, or at least are not inconsistent with it. Thus conceived, a universal, this-worldly, science-based religion is emerging. If we are to have One World, it must be religious as well as political and economic.

BEFORE a rational rather than a rationalized religion can be achieved, the secular myth must also die. Secular myths are perhaps more pervasive, and are certainly more deadly, than sacred myths have ever been. If the latter have slain their millions, as they have, the former, directly and indirectly, have slain their tens of millions. Frequently, the secular myth is a verbal transformation of some previously vital sacred myth. The will of the gods becomes the will of the Führer, dictator, or great man; the kingdom of God becomes a dynastic kingdom, or the manifest destiny of a democratic state, or the "mission" of a proletarian or fascist dictatorship. As the sacred myth grows dim, it is replaced by some shining secular myth which fascinates and blinds its devotees. To propagate and defend such myths, men persecute and kill their fellows and destroy the wealth and culture of mankind.

All myths, whether sacred or secular, are based on the philosophy of "all or nothing." Their world is black and white, good and evil: "Ye cannot serve God and Mammon;" "Those who are not for us are against us." They coerce thought and action; they are ruthless, exploitive, and destructive; they flout facts; they tolerate no questioning; they require absolute loyalty and permit no compromise and no adverse criticism. Secular myths employ all the fine arts of verbal protective coloration and rationalization and manifest themselves in many forms. For example, when nazism is reduced to rubble, there are no Nazis in all Germany. Republicans and Democrats reverse their historic roles on States' rights when their positions of power and responsibility are reversed. The secular, like the sacred myth, is a semantic chameleon.

intro

Secular myths are found in all areas of our culture, but they are most numerous and dangerous in the fields covered by social science. Secular myths connected with physical and biological phenomena are generally regarded as evidence of sheer ignorance about physical and biological science. These sciences have been so well justified by their works, by the practical application of their findings, that myth-mindedness in these fields is small and rapidly decreasing. Likewise, the intensity of belief in such myths and willingness to act in accordance with the logic of the myth are rapidly decreasing. Probably there are few people in the United States who, if they had the power, would burn anyone at the stake for denying that the earth is flat and does not move or for asserting that surgery is better than prayer for acute appendicitis.

The case is quite different with secular social myths. Mankind does not yet clearly recognize that social phenomena are natural phenomena and that the social sciences are, or may become, natural sciences. Social arrangements still are based largely on the trial-and-error, common-sense knowledge developed when the tribe was small and isolated and man won his daily bread by hand and horse and simple tool. The myths that "worked" then have become progressively unworkable in a culture revolutionized by physical and biological science. Modern culture no longer can be observed and comprehended by naive common sense. The only alternative to mounting social chaos is the scientific study of social phenomena. The shock of the atomic bomb has awakened some nuclear physicists to this necessity. Other scientists and millions of intelligent laymen are calling upon social scientists to "save us," but the tragic fact is that there is no body of basic and applied social science capable of doing the job; nor is there a sufficiently large body of public opinion ready to accept the findings of social science if they did exist. Myth-minded politicians can remove the social sciences from the National Science Foundation without causing a great outburst of public indignation and, more significant, without causing

more than a small ripple of dissent from physical and biological scientists. Even the social scientists themselves do not seem much concerned. It is a disturbing fact that, while most secular myths are in the realm of social phenomena, mankind in general, including (possibly) most physical and biological scientists and many so-called social scientists, is still largely myth-minded with reference to social phenomena.

Only a few secular social myths can be mentioned here. Some of them, such as slavery, the divine right of kings, and the "iron law of wages," run like blood-clotted threads through the web of history. Some are still vital myths in whose service millions of men are yet destined to die. Most of them are still linked to crude or subtle sacred myths or to metaphysical concepts derived from sacred myths. Consider the ideas, feelings, and actions connected with the following concepts: the great-man theory of history; the many forms of racism, classism, statism, nationism, and imperialism; absolute sovereignty; manifest destiny; the white man's burden; perfect competition and the economic man; free enterprise; free trade; protective tariffs; the profit motive; the gold standard; Marxism; communism; nazism; fascism; democracy; consumers' cooperation; labor organization; equality; education; science; advertising; eugenics; euthenics; dietetics; athletics; alcohol; monogamy. Many more could be added.

All refer to types of social behavior that are highly important to all people. All are capable of scientific analysis. Much available scientific knowledge would throw some light upon the social problems connected with them. However, most people, including economic, political, religious, and educational leaders, think about them and deal with them mythically. One may be "for" or "against" any of them in a thoroughly myth-minded manner and still be highly respected. One is in bondage to a myth when his thought and action are not characterized by reason, suspended judgment, critical-mindedness, and readiness to modify his behavior in accordance with scientific evidence and tested experience. A concept is a myth when it is held to describe necessary, "natural," innate, and immutable behavior; when it is regarded as sacred and requires unquestioning allegiance; when it is treated as self-evident and engenders intense and passionate certitude; when those who criticize its validity or implications are branded as dangerous, traitorous, wicked, and stupid; and especially when it is held to be the revealed or "intuited" purpose of "higher powers." Secular myths have some of or all these characteristics.

A secular myth is a stereotype of a cherished value, usually based on hope or fear. It is above criticism and generates positive and negative behavior—mores and taboos. It exercises coercive control by irrational fears, utopian hopes, rosy promises, black threats, and ruthless force. It uses all the suggestion techniques of mass appeal: glittering generalities; folksy common sense; class consciousness and snobbery; pseudo science; transfer of affect; twisted interpretations of history and experience; repetition; testimonials; exaggeration; copious citation of alleged authorities; promises of prosperity and security; escape from all tensions, fears, and discontents. Usually the secular myth, like the sacred, is supported by prestige symbols, rituals, ceremonies, and routines for inducing compliant, uncritical, conventional, collective behavior. If you would escape the physical and mental coercion of the secular myth, beware of the man with a flag, a uniform, an oath, or a ritual of magic words. Slogans, jingles, catch phrases, and trade-marks are indicators of the secular myths served by politicians, advertisers, and special pleaders of all kinds.

Since most vital secular myths in our culture are related to social phenomena,

it may be profitable to look for evidences of myth-mindedness in the field of the social sciences. All of them were full of it before 1900, and none of them are free of it today. There has been considerable improvement in recent years, however, as more and more social scientists have come to regard their fields as natural sciences. It is a dangerous thing to suggest that a scientist in any field is a myth-maker or a myth-monger, since science and myth are contradictions by definition. It is almost equivalent to accusing him of being no scientist and yet, in the light of this analysis, it would be presumptuous for any social scientist to protest too vigorously that there is no mythic element in his thinking. A myth can be recognized only when its vitality is ebbing; it *is* a myth only after it *was* a myth. The adherent of any still vital sacred or secular myth cannot admit it because he regards it as the final and unadulterated truth—one of the major criteria of myth-mindedness. The mythic elements in the ideas of social scientists often are excused or overlooked by them and others by being called overemphasis, underemphasis, or specialization. Social scientists who introduce into their work any variety of animism, however modernistic and metaphysical, are not natural scientists at all. This includes those who assert that "man is different" from other natural phenomena, that his social arrangements are the result of the will of the gods, or God, that there are teleological and occult forces in the world, or that man is really a "spiritual" being. These things may all be true, but they are unnecessary hypotheses for natural science.

The universe postulated by natural science is an unending series of energy transformations. Every event is caused, but causation, in the most general sense, means that every event is the resultant of all antecedent events. Hence, every event is different from every similar event that has ever occurred. The universe is constantly changing because every energy unit within it is never the same for any successive instant. Scientific knowledge is gained only through the senses, usually aided by instruments, and the logical generalizations, including inferences, constructed from these properly symbolized sensory experiences. Since the senses are inaccurate, limited, and constantly changing, as are all instruments and observable phenomena, and since logical processes are conditioned by culture and the past experience of the knower, therefore all apparent uniformities are relative to some "taken" standard or frame of reference, and all predictions are approximations and probabilities. There is no absolute identity or repetition of events, objects, or relationships. The constants of science are sensory responses, usually mediated by instruments, which are generalized according to the logic of a given, or "taken," set of assumptions or postulates. Thus there can be no absoluteness, finality, or eternal verity about the findings of science. They are limited, relative, and subject to change in the light of new scientific knowledge.

Natural science is possible because the sensory responses and mental mechanisms of mankind are relatively similar and because many classes of natural phenomena are relatively stable and repetitive. "Relative" means in comparison with some standard adopted by man. Such standards are not wholly arbitrary since they are dependent upon the kind of responses possible and common to the kind of organism man is. When descriptive and predictive generalizations exceed those of common sense in range, accuracy, and usefulness, they are scientific knowledge. It should be noted that most sensory responses to the physical, biological, and cultural environments are not scientific and probably never will be. They remain private (subjective); if they are communicated at all, it is on the level of common sense. However, scientific knowl-

edge is rapidly growing in all three fields of natural science. The result is decreasing reliance upon supernatural explanations, which tend to fall into disuse and disbelief and to become outmoded sacred myths. Therefore, social scientists who introduce animistic conceptions into their work are likely to be regarded as adherents of crude or covert sacred myths.

It has been suggested that most social scientists, like the rest of us, though probably to a somewhat lesser degree, are influenced by current secular myths. The more strictly one is guided by the ideology and methodology of natural science, the less mythic his thinking is likely to be. There is a subtle mythic element in the conviction that one's own specialty is "basic and fundamental" and capable of "explaining" all other forms of social phenomena. The history of the social sciences is full of such cases, and the halls of Academia are still infested with such men: economic, political, familial, religious, educational, and even scientific determinists; devotees of the genes, the I.Q., the soil, the climate, and so on. All single-factor, oversimplified explanations of social phenomena and remedies for social problems are mythic. A nonmyth-minded social scientist cannot be an uncritical, dogmatic, all-or-nothing adherent of Marxism, capitalism, democracy, or any other ill-defined, all-inclusive concept based on hope and fear. His business as scientist is not to promote, but to perceive and previse.

A man is myth-minded when he becomes obsessed by some particularistic methodology or theoretical point of view to the exclusion of all others. He is ready to brand other scientists as "not scientists" if they do not share his methodological manias and phobias. Some men make a fetish of mathematics and thus transform the most useful and powerful scientific tool into a magic wand; some do the same with logic and semantics; others are addicted to case-study methods and folksy natural-history descriptions; there are Marxian, Freudian, Meadian, Aquinian, and Marshallian social scientists; gestaltists; behaviorists; ecologists; social anthropologists. Some are in bondage to authority and assert that all social knowledge can be found in the works of ancient men, perhaps in a Hundred Best Books—research is really re-search to them; others argue *ad hominem*, by analogy, and employ the imprecise language of the literary arts. Some are in bondage to words and invent personal, neologistic vocabularies not based on new data or new analysis of old data. Some men even become famous by giving an old idea a new name; for example, "drive," or "prepotent reflex" for instinct, or "extrasensory perception" for mental telepathy and clairvoyance.

There are symptoms of subtle myth-mindedness in a man who is still bothered by the relationship between science and values, "pure" and "applied" science, or quantitative and mensurative versus other methods of research. It is evidence of myth-thinking to be confused by the relations between the physical, biological, and social sciences and to wonder whether the social sciences are "really" natural sciences; or to be disturbed by the nature and relative value of inductive, deductive, empirical, and inferential facts and theories. These are elementary matters that will not confuse any social scientist who is a competent natural scientist. Those who are disturbed by them are still in bondage to some form of sacred or secular myth.

All scientists are relatively free from both crude and subtle sacred myths. Most social scientists are freer than their physical and biological colleagues from secular myths. If the rest of mankind were as scientific-minded about social phenomena as social scientists are, a fairly safe and sane social order might be constructed in the next fifty or one hundred years. It would

require only the wholesale application of existing social science knowledge and an accelerated program of basic and applied social science research in all fields. The scientific habit of mind and scientific knowledge are lethal to all forms of sacred and secular myths. Unfortunately, the scientific attitude cannot be produced on the assembly line or dropped into culture like an atomic bomb. Myths die slowly, mostly by attrition, and often prolong their lives by rationalization and subtle forms of restatement. This is well illustrated by the present state of the sacred myths—they still exist but do not prevent many people from using the findings of science.

Secular myths also die slowly and often manifest themselves in subtler forms, but they finally die, either in social cataclysm or by the slow but steady increase of common sense and scientific knowledge. Slavery went out in an orgy of blood and fire. The divine right of kings rotted away for centuries and finally died by revolution. Some secular myths, like "Spare the rod and spoil the child," have died by attrition, but some now plaguing society may not die before they have produced wholesale death and destruction. Consider the rising race tensions all over the world, the mounting intensity of labor-capital conflict, the exploitation of backward peoples, the confusion, apathy, and callous fatalism regarding the abolition of war. It seems unlikely that enough secular myths will lose their vitality soon enough to falsify the ancient adage: "Without the shedding of blood, there is no remission of sins."

A deliberate attempt to disseminate the scientific habit of mind widely, especially as it pertains to social phenomena, might hasten the decay of secular myths. To do so, however, would require a revolution in education, politics, and industry. Some method would have to be found to raise the prestige and perhaps the financial rewards of basic and applied social science research and teaching so that the ablest people would enter these fields for the next generation or two. It is painfully obvious at present that our best brains are not found in the social sciences. Children could no longer be told lies and fairy tales—they would have to be oriented to the world as science sees it; religion would have to preach only such doctrines as are consistent with the methods and findings of science; artists of all kinds would have to eschew fantasy and espouse facts; politicians, publicists, and businessmen would have to be well-grounded in the social sciences and trained professionally to think and act in terms of world public welfare rather than in terms of personal, class, and narrow nationalistic interests. This will all happen in due time, including the development of an effective world government, but it seems unlikely that it will happen before Atomic War I, before strikers have been shot and gassed, before millions have died from preventable disease and starvation, and before race riots have occurred in India, South Africa, and all over the United States.

To close on such a gloomy note violates the genial myth that all things work together for good to them that love mankind. When a myth is waning, its frightened defenders always cry out for a "return to reality," by which they mean some new myth or some rationalized version of the old. This is the hopeful note: such cries are always in vain; mankind cannot go back; there is no lasting vitality in any sacred or secular myth. In the dark confusion produced by all dying myths, mankind has always found some new light and new hope. In this age, that hope is natural science—physical, biological, and social. Perhaps sooner than now seems likely, man will escape from the irrational fears and actions that have characterized him throughout his history and achieve a social organization in which men can live integrated lives under the guidance of science.

Some not too subtle metaphysician may argue that this emphasis on natural science is itself an instance of myth-making. Perhaps the only answer is this: if science is a myth, it is so powerful that it threatens to destroy all other myths. It is delivering the "goods" of life in ever-increasing abundance. The Age of Science may be less gruesome and grisly than the Age of Animism has been. At any rate, increasing millions are accepting science as their "one last best hope on earth." Science-making must destroy myth-making or science itself will be destroyed. The most powerful agency for doing this is the rapid development and world-wide dissemination of the natural sciences of social life. This is the world-shaking and world-remaking idea that is capturing the imagination and allegiance of humanity.

The most significant question in the world today is this: Can the physical, biological, and social natural sciences be organized and utilized for human welfare? Will the Age of Science serve man or destroy him? Perhaps the greatest single menace at the moment is the danger of war before the integrating forces of science can destroy enough sacred and secular myths to destroy war as cannibalism, human sacrifice, slavery, and blood revenge have been destroyed. The present effort may succeed. If it fails, success may come after Atomic War I, or even after Atomic War II. It may require the shock therapy of 20,000,000 tons of TNT, or one atomic bomb, in mid-Manhattan to shake mankind out of bondage to the myth of absolute state sovereignty. The hopeful note is that man is beginning to realize that he can destroy, or save, himself; that he can choose, and his choice is his destiny.

COMMITTEE ORGANIZATION, CHICAGO MEETING, A.A.A.S., DECEMBER 26-31, 1947

Paul A. Jenkins, Executive Secretary of the Chicago Technical Societies Council, has been elected by the officers of the local committees to preside as General Chairman of the 114th Meeting of the A.A.A.S. to be held in Chicago, December 26–31, 1947.

Representatives of fifteen educational and cultural institutions in the Chicago area are serving on five committees:

Equipment Committee
Chairman: R. T. Van Niman, Chicago Technical Societies Council

Publicity Committee
Chairman: Jeannette Lowrey, The University of Chicago

Finance Committee
Chairman: W. P. Cortelyou, Roosevelt College

Reception and Entertainment Committee
Chairman: George M. Schmeing, Loyola University

Registration Committee
Chairman: Hans Hoeppner, The University of Chicago

As hosts to the scientists attending the Convention, members of these committees will arrange for the General Reception, provide equipment for the sessions, organize special tours, and provide information on facilities for dining and travel and descriptive circulars on points of interest in the greater metropolitan area. The Finance Committee will raise the funds necessary to defray the expenses of the other committees.

The organization of local committees to direct the annual meetings of the Association gives scientists an opportunity to cooperate in major civic enterprises and each year provides the Association with new viewpoints for the improvement of its meetings. The members of the local committees have projected plans for the Chicago Meeting that promise to make it one of the most successful in the history of the Association.

IN DUE PROPORTION

By H. H. BLISS

Mr. Bliss holds two degrees in engineering from the University of California and now teaches engineering subjects at the Riverside College, Riverside, Calif. Long interested in photography, he takes landscape photographs in his extensive travels in the deserts and mountains of the Western states. Lately he helped to navigate a small sailboat from Hoover Dam to the mouth of the Grand Canyon, photographing the surrounding desert landscape.

TO UNDERSTAND the fundamentals of lens action, the photographer makes use of that same sense of proportion that enables him to plan a satisfying composition. It is applied in a different manner, however, through the use of some simple algebra and geometry. Such questions as (1) Which lens should be employed to reduce a certain building to the size of a 4 x 5 film? or (2) How far should the lens be pushed out beyond the end of the focusing scale to get a close-up of a flower? or (3) How should the lens be focused and what stop should be used if a nearby person and a more distant sailboat are both to be in the same picture and reasonably sharp on an 11 x 14 enlargement? are typical of the problems soluble in this way.

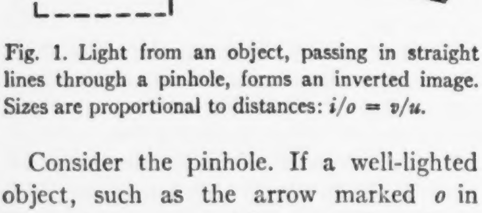

Fig. 1. Light from an object, passing in straight lines through a pinhole, forms an inverted image. Sizes are proportional to distances: $i/o = v/u$.

Consider the pinhole. If a well-lighted object, such as the arrow marked o in Figure 1, is separated from a wall, w, by a partition pierced by a small hole, rays from o will travel in straight lines through the hole and strike the wall, forming an image, i, upside down, and larger or smaller than o in proportion to the distances v and u. (It is obvious on inspection that the two triangles are "similar," that is, the corresponding angles are equal in the two cases.) We write:

$$i:o::v:u, \text{ or } i/o = v/u.$$

The size of the image is to the size of the object as the image distance is to the object distance.

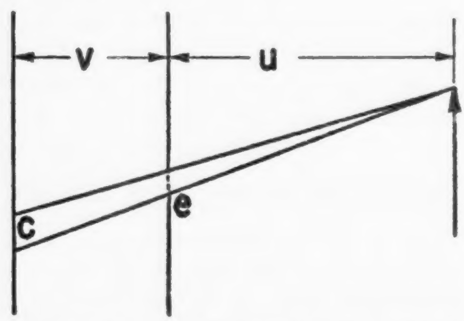

Fig. 2. Circle of confusion, c, is larger than the pinhole: $c/e = (u + v)/u$. With a large hole the image becomes too blurred to be useful.

This simple apparatus may be considered to represent a camera, but one objection to using it in practice is the dimness of the image, which would necessitate a long exposure if we tried to take a picture by putting a film against the back wall. Evidently not enough rays of light get through the tiny opening, although we know that millions of rays are coming from any point on the object, because we can see it from every side. Making the hole larger catches more of the rays, but, as shown in Figure 2, they tend to spread even wider

than the size of the hole before they reach the film and so form an image made up of overlapping spots of light. Letting c stand for the diameter of the "circle of confusion" and e for the diameter of the hole through which the light comes, we have the proportion:

$$c/e = (u + v)/u,$$

since the whole triangle is similar to the smaller one (with its base at e).

If we put a simple lens of proper curvature in the opening, we secure an image both bright and sharp, but of the same size as before. A ray that passes through the

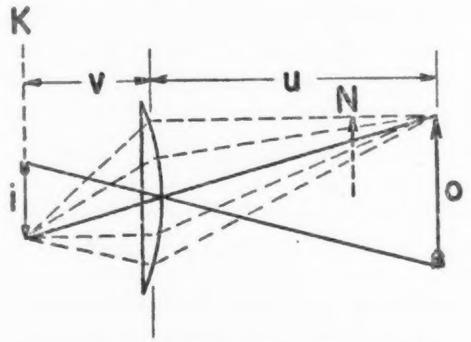

Fig. 3. The lens catches more rays than the pinhole and brings to a point those leaving a single point of the object. Proportionality still holds: $i/o = v/u$.

center is still straight, just as with the pinhole, but all others from the head of the arrow are bent by the lens so as to come together at the lower end of the image (dash lines, Fig. 3). So, also, the rays from the foot of the object (all which strike the lens) converge to the top of the image. As far as picture size is concerned, we may imagine the lens to be replaced by a pinhole at its center, and set up the old equation:

$$i/o = v/u.$$

(Actual lenses do not work quite so perfectly as imagined here, but the difference is small enough to forget in this discussion.) We assume, then, that there is a zero circle of confusion at the focus of our lens.

If the arrowhead in Figure 3 is moved nearer to the lens, say to point N, the lens will no longer be able to bend all the rays so that they meet at a point on the film. A ray striking a given point on the lens is bent just about the same amount no matter at what angle it strikes, so now the point of convergence comes farther back, as at M in Figure 4, and if the film remains at K there is a definite circle of confusion instead of a point image. We say that it is "out of focus."

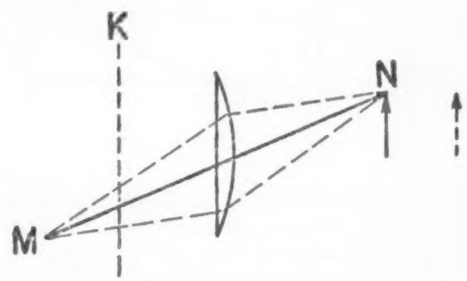

Fig. 4. If the object comes closer to the lens, its image moves away, and if the film remains at K the image of point N is shown as a circle of confusion.

The focus of a lens is primarily the place at which the image of a very distant object is formed, but the word is also used to refer to the distance from that image to the center of the lens, which is better called the focal length. Some confusion arises from the use of the word "focus" for the distance v in Figure 3, which is properly designated as "image distance." The focal length, f, of a lens is, then, the image distance for an object at infinity. Whenever the object is nearer, v must be greater than f. The actual relationship between v, f, and the object distance, u, can be found by applying the law of similar triangles to Figure 5.

Let F be the point on the axis of the lens where the rays would meet if they came from a point on the axis of the lens very far to the right. Such rays, before

striking the lens, would all be practically parallel to the axis. Now, if object o is set up at a short distance, u, from the lens, one ray can be drawn from the top parallel to the axis and bending down through F. (It does not stop there, unless there is an obstacle.) Let F' be the other focal point, the place where rays from a very distant object on the left half of the axis would meet if passing to the right through the lens. Conversely, any ray from F' that strikes the lens will run out leftward parallel to the axis. We select one coming from the

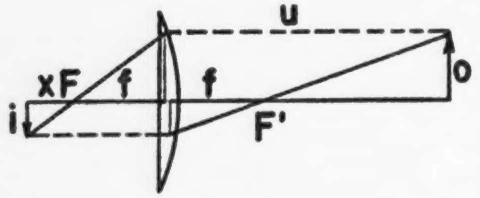

Fig. 5. On a camera the focusing scale is based on the distance, x, from the principal focus, F, back to the image: $x = f^2 \div (u - f)$.

top of the object, passing through F' and ultimately meeting the first ray as shown. Here is the image of the top of the object, for all other rays from the head of the arrow which strike the lens are brought to the same point.

We now have two similar triangles at the left of the lens. Note that the distance in the lens up to the dotted line $= o$; hence

$$i/o = x/f$$

where we use x to designate the distance from the focus to the image (which is the distance the film must be pushed back from its "infinity position" to focus on the nearby object). On the right of the lens are two more triangles which yield the proportion:

$$i/o = f/(u - f).$$

Hence:

$$x/f = f/(u - f) \text{ or } x = f^2/(u - f)$$

(by multiplying both sides of our equation by f).

This is an important formula. The first use of it is to make a focusing scale. Suppose we have a 4-inch lens; then for 50 feet (600 inches) we figure

$$x = 4 \times 4/(600 - 4) = 16/596 = 0.0268'';$$

for 10 feet, x comes out $16/116 = 0.138$ inch; for 3 feet, $x = 16/32 = 0.5$ inch. These are the distances to move the film *back* (or the lens *forward*) to focus sharply on objects at 50, 10, or 3 feet. In the event that we must photograph an object that is closer than any mark on the focusing scale, say, at 2 feet, we figure $16/(24-4) = 0.8$ and measure 0.8 inch from the infinity mark to find the proper setting. Again: Suppose the bellows will permit just 1.25 inches movement beyond the infinity mark; how close can we put something and portray it sharply? Set

$$1.25 = 16/(u-4), \text{ or } u-4 = 16/1.25;$$

whence

$$u-4 = 12.8 \text{ and } u = 16.8''.$$

For most cases the simplified formula

$$x = f^2/u$$

gives almost the same result and is easier to use. In the example above, x for 50 feet would have come out 0.0266; for 10 feet, $x = 0.133$; for 3 feet, $x = 0.444$. Hence, we use $x = f^2/u$ except for very close objects.

Depth of focus is most interesting to the photographer. Together with terms like "depth of image" and "depth of field" it refers to the problem of getting into one picture satisfactorily sharp images of near and distant objects. The first thing to settle is the meaning of "satisfactorily sharp." A commonly accepted criterion is that the circles of confusion in the final print must not be greater than 0.01 inch across, as it is usually considered impossible to notice this much blurring in a picture held 10 inches from the eye, the normal distance of

most distinct vision. Let us assume, then, that this is our limit.

Suppose we have a miniature camera with a 2-inch lens. We probably will not care to make contact prints and look at them 10 inches away. For one thing, they will give false perspective, and for that reason alone it is desirable to enlarge 5 diameters, so that the pictures look as if taken by a 10-inch lens. A glance at Figure 1 will make it clear: If from a position at the pinhole one looks at either the image or the object, one gets the same angle between the top and bottom of the arrow and hence has the same sized picture in the eye. After the photograph is finished it should be examined from a distance equal to v, or approximately f in most cases. If a negative is made with any other than a 10-inch lens, it should be enlarged (or reduced) to make it equivalent to a 10-inch lens picture if it is to be viewed at 10 inches. Furthermore, if part of our miniature negative is enlarged 15 diameters on 11 x 14 paper, the picture is now similar in perspective to one taken with a 30-inch lens ($15 \times 2 = 30$) and should be viewed 30 inches away to get an impression similar to that obtained from the original scene. This means that the circles of confusion can be 0.03 inch across (unless the print is to be criticized by someone who insists on viewing everything at nose's length because he never heard of perspective).

By similar triangles applied to the enlarger, we find the size of the allowable circle of confusion in the negative. If 5-diameter enlargement is needed to make a print to be viewed where $c = 0.01$ inch, then c must be 0.002 inch in the negative. In general, $10/f$ is the enlarging ratio to get this kind of print, and hence $.01 \div 10/f$, which equals $f/1{,}000$, should be the value of c for the negative. We take this as standard in what follows.

Suppose we have a perfect lens and set it f inches in front of a film; then a very distant object will generate an image on the film with no confusion at all. But any nearer object will try to make an image behind the film, and hence produce on the film a blurred picture with circles of confusion of diameter c (Fig. 6). If e is the diameter of the diaphragm stop,

$$c/e = x/(f+x),$$

which we shall write

$$c/e = x/f,$$

since f is within a few percent of equalling $f + x$ in most practical cases. Transpose this to

$$c\,f/e = x$$

and substitute S for f/e, so that it becomes

$$c\,S = x.$$

(Note that S is the "stop number;" when we "stop down to 11" it means that the focal length divided by the diameter of the hole equals 11.) Now let us find the distance, H, to the near object. Previously we found that

$$x = f^2/u$$

where we took u for that distance, so now we write

$$x = f^2/H.$$

Therefore,

$$c\,S = f^2/H,$$

from which we get

$$H = f^2/c\,S.$$

Every object more distant than H will be rendered with a smaller circle of confusion, and hence satisfactorily sharp if c is $f/1{,}000$.

We have found, then, a fairly simple formula to tell us how far away is the nearest object that can be photographed when the lens is focused for a very distant one. This distance, H, is called the "hyperfocus" (or, more accurately, the "hyperfocal dis-

tance"), and it is readily calculated by dividing the square of the focal length by the product of the stop number times the diameter of the circle of confusion. For example, with the 2-inch lens at stop 8, with c assumed as 0.002 inch, we have

$$H = 2 \times 2/0.016 = 250'', \text{ or } 20.8'.$$

If we take $c = f/1{,}000$, our formula becomes:

$$H = f^2 \div (S\,f/1{,}000) = 1{,}000\,f/S$$

(H in inches if f is in inches), or

$$H \text{ (in feet)} = 83\,f \text{ (in inches)} \div S.$$

In metric units,

$$(H \text{ in meters}) = f \text{ (in millimeters)} \div S.$$

One may, at this point, begin to question the wisdom of setting the focus on infinity, arguing that by focusing on some nearer point one could still get satisfactory definition for extreme distance, and also record satisfactorily objects closer than the hyperfocus. The natural impulse is to set on the hyperfocal distance itself and see what happens. Figure 7 shows the rays from infinity crossing at F and spreading again to make a circle of confusion on the film which has been set back by the amount ($x = f^2/H$) specified above. Then

$$c/e = x/f,$$

so that, if x, e, and f are the same as before, c must also be just the same size as in Figure 6, since the equations are identical. Now we have infinity sharp enough, and objects at the hyperfocus absolutely sharp (assuming we have a perfect lens).

An object moving closer from H will be rendered more and more blurred until a point is reached where the circle of confusion equals that for infinity (Fig. 8). That point is about half as far away as the hyperfocus, as proved by the following:

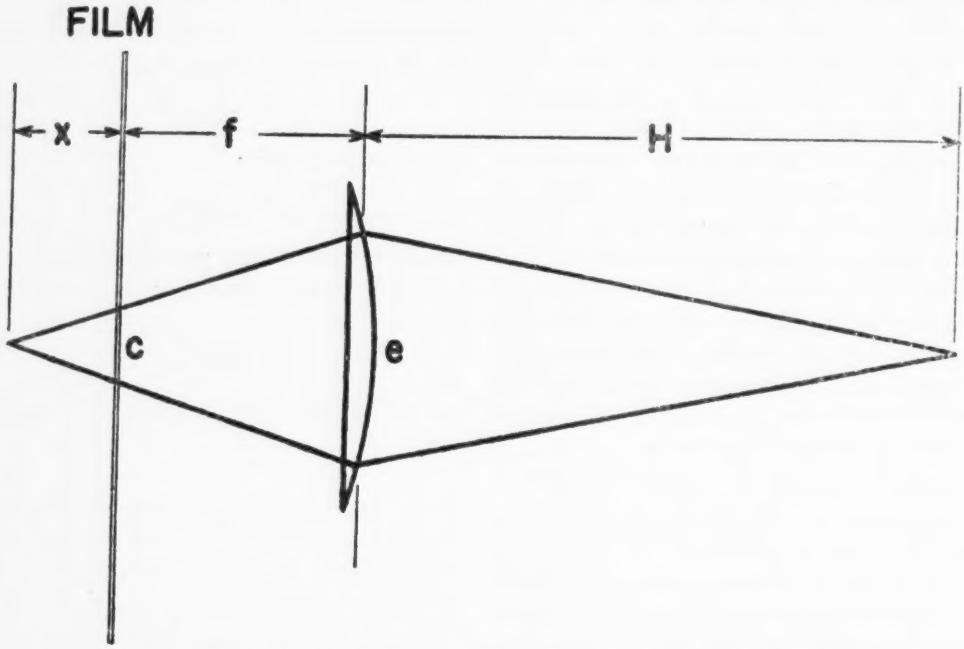

Fig. 6. With the film at the principal focus (infinity position), a nearer object, at H, produces an image on it with circles of confusion: approximately $c/e = x/f$, whence $x = cS$ if S is the stop number.

Note that the two little triangles are almost similar, though the exaggeration of the sketch tends to emphasize their difference—if c is 0.002 inch and f is 2 inches, it is clear that the angles will be almost exactly equal. Then the x for the near object, being

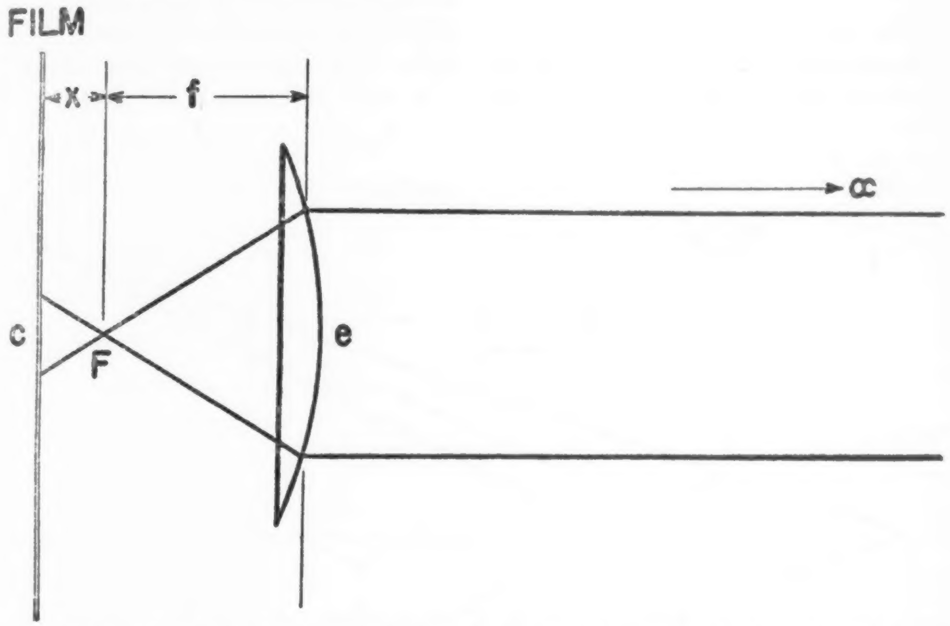

Fig. 7. With the film set back far enough to get perfectly sharp images of objects at the hyperfocus, very distant objects are rendered with the allowable circle of confusion, and hence satisfactorily sharp.

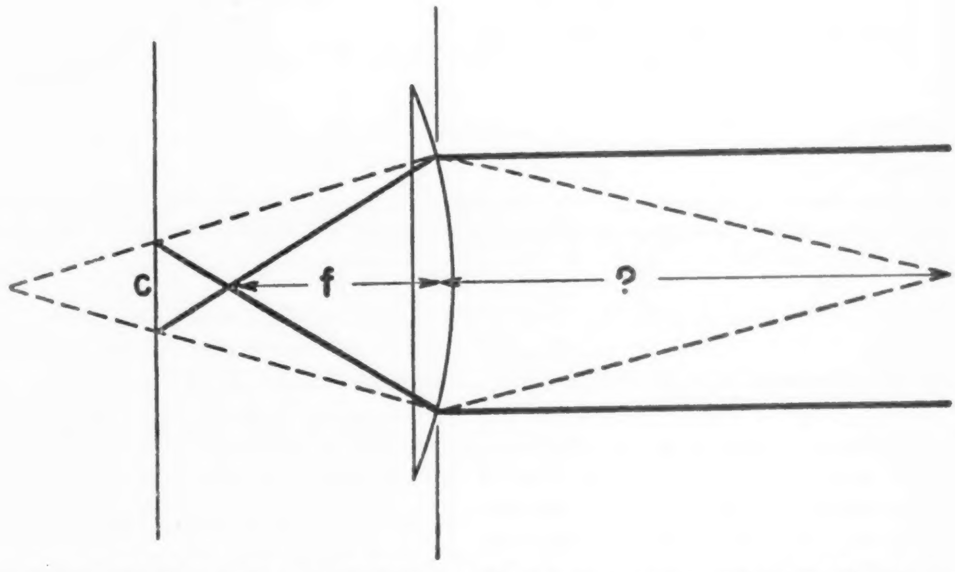

Fig. 8. When the film is set for perfect definition of objects at the hyperfocus, satisfactorily sharp images are produced for everything from infinity down to half the hyperfocal distance.

the sum of the lengths of the two little triangles, will be twice the x of one, which corresponds to an object at the hyperfocus. From the approximate formula

$$x = f^2/u$$

we see that when x is doubled u must be cut in half: for example, with the 2-inch lens when u = 250 inches, x for that is $2 \times 2/250$, or 0.016 inch, and, for an object at 125 inches, x is $2 \times 2/125 = 0.032$ inch.

To sum up all this in a simple rule: Set the focusing pointer at the hyperfocus which, in feet, equals 83 times the focus in inches divided by the stop number: then everything will be sharp from half the hyperfocus to infinity.

More often than not, one's interest is in near rather than in distant objects, and here the question of depth is even more important. If we focus on the principal object at distance P, what is N, the distance to the nearest, and D, that to the most distant, object to be rendered with circle of confusion c ? In Figure 9 the little triangles, with apices marked n and d (where sharp images would be formed for objects at N and D) are nearly alike, so we equate the horizontal lengths of the two:

$$f^2N - f^2/P = f^2/P - F^2/D,$$

which reduces to

$$1/N + 1/D = 2/P$$

when we divide both sides by f^2 and transpose the negative terms. Call this Equation

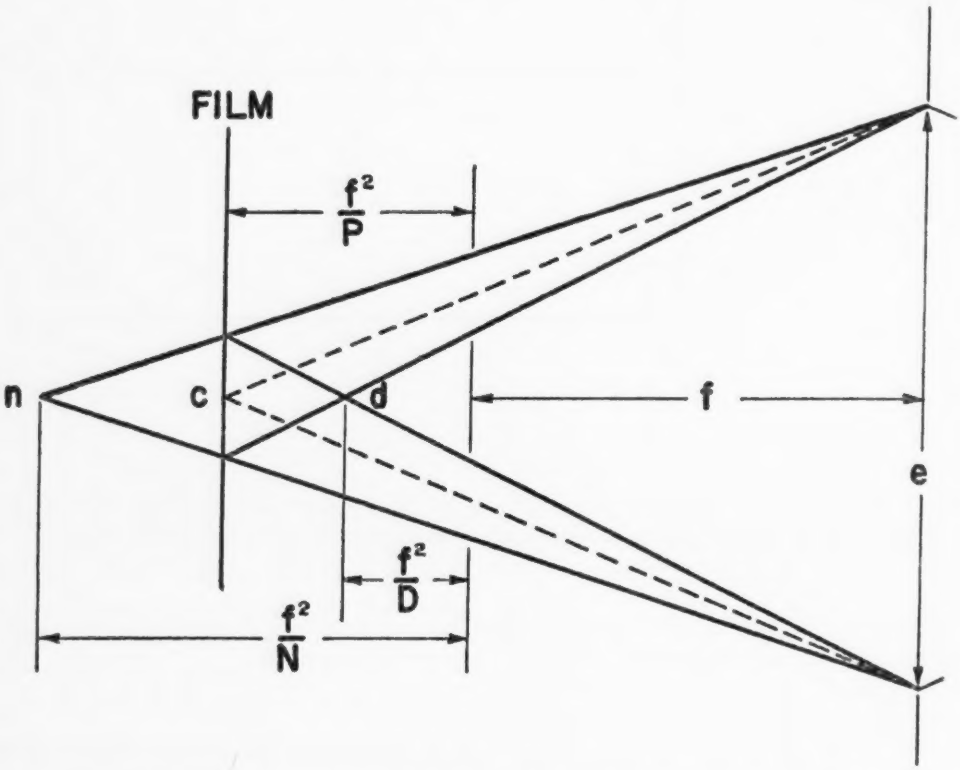

Fig. 9. The film is placed to get a perfectly sharp image of a principal object at distance P (rays shown dotted), and objects at distances N and D produce on it images with circles of confusion c. $N = HP/(H + P)$; $D = HP/(H - P)$.

1. Next we take the average length of one little triangle as

$$(f^2/N - f^2D) \div 2$$

and set up the proportion that this is to c as $(f + f^2/P)$ is to e. For simplicity we may say that f is so nearly equal to $f + f^2/P$ that we write it:

$$f^2/N - f^2/D = 2\,c\,f/e = 2\,c\,S$$

(since f/e is equal to the stop number S). But

$$c\,S = f^2/H,$$

as shown above, and therefore

$$f^2/N - f^2/D = 2\,f^2/H, \text{ or}$$
$$1/N - 1/D = 2/H.$$

This is Equation 2. If we add the two equations, we find

$$2/N = 2/P + 2/H, \text{ or}$$
$$1/N = 1/P + 1/H,$$

which enables us to compute the near distance if we know H. Subtracting Equation 2 from Equation 1 gives

$$2/D = 2/P - 2/H, \text{ or}$$
$$1/D = 1/P - 1/H,$$

which gives us the far distance. These two formulas are usually transformed into a slightly handier form:

$$N = H\,P/(H + P) \text{ and}$$
$$D = H\,P/(H - P).$$

Thus, if we have stopped down our lens till the hyperfocus is 30 feet, and we focus on 20 feet, the nearest object that will look sharp is at $30 \times 20/50 = 12$ feet, and the most distant at $30 \times 20/10 = 60$ feet.

This disproportion between 8 feet on the hither side and 40 feet on the farther side of the principal object suggests that it is not the best practice to focus halfway between two objects which must both be sharp. Returning to Equation 1, we find that

$$2/P = 1/N + 1/D,$$

from which P can be found. It is more useful in the transposed form:

$$P = 2\,N\,D/(N+D).$$

Note that this is independent of the stop or the hyperfocus and always gives the setting to get near and far objects equally sharp. For instance, to photograph people at both

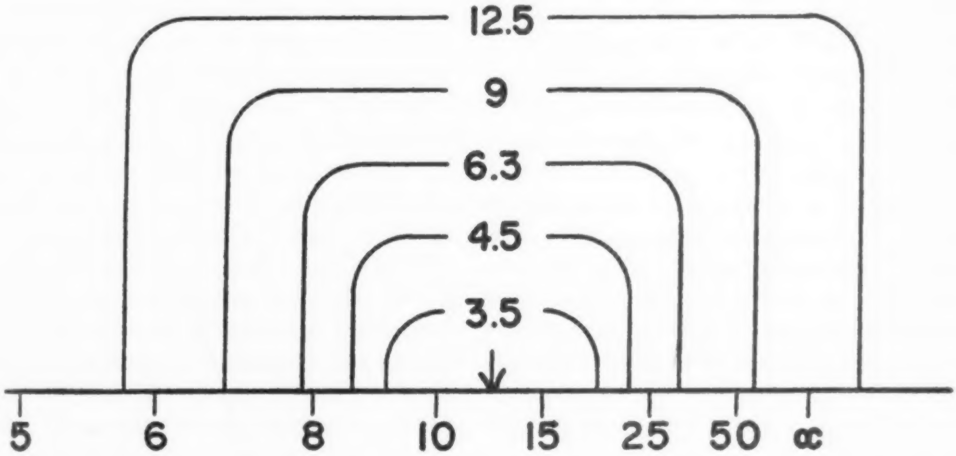

Fig. 10. The depth of focus scale. With stop 6.3 the image will be satisfactorily sharp for any object between 8 and 30 feet away.

6 and 12 feet away, set on $2 \times 6 \times 12/18 =$ 8 feet.

Found on some modern cameras is an automatic gadget known as the "depth of focus scale," which performs mechanically all this complicated mathematical drudgery. It replaces the ordinary pointer which runs along the focusing scale and, as shown in Figure 10, it consists of a set of concentric brackets, each marked with a stop number. In use, it tells at a glance just what objects will be in sufficiently sharp focus at any distance setting and any stop; in the figure the camera is set for 12 feet, and, if stop 6.3 is used, everything will be sharp from 8 feet to 30 feet. Again, if we must get into one photograph things at 5 and 50 feet, we move the depth scale until some bracket spans this space on the focusing scale: the one marked "12.5" would do it in this case. The lens to which the depth scale is attached now is properly set to give equally good definition for objects at 5 and 50 feet, and at stop 12.5 the circle of confusion would not exceed the limiting value used in computing the depth scale. If one desires to know the hyperfocus at any or all stops, one merely sets the arrow on infinity and reads the answers on the focusing scale under the proper lines on the other.

The depth scale, then, is simply a set of hyperfocal distances interpreted in terms of the focusing scale. In Figure 10 the arrow is on 12 feet, and that is the hyperfocus for stop 11, so that with this setting everything is sufficiently sharply rendered from 6 feet to infinity.

Why the device works equally well at any place on the focusing scale will be clear from the fact that each of the little triangles of Figure 9 is nearly constant in size, whether the objects being photographed are near or faraway. The distance the film can depart from the position of sharpest definition before the circle of confusion gets too large is also constant, and equal to the space along the scale from the infinity mark to the hyperfocus mark.

If one's camera lacks a depth scale, it is an easy matter to design one by simply calculating hyperfocal distances for all the stops marked on the shutter from:

$$H \text{ (feet)} = 83 \times f \text{ (inches)}/S, \text{ or}$$
$$H \text{ (meters)} = f\text{(millimeters)}/S.$$

Then, putting the arrow on the infinity mark, one gets the half-width of each bracket. With a lens of $f = 1.6''$, H for stop $3.5 = 83 \times 1.6/3.5$, or $38'$; for stop 9 it is $83 \times 1.6/9 = 14.8'$. Figure 10 was computed for this lens. With such a small lens, it is necessary to expand the focusing scale to make it legible; generally the lens is moved in and out by rotating it in a threaded shell, and the scale runs around the barrel. Then the depth scale is correspondingly large and easily read. It is shown here about 100 times true size.

With a lens of long focus, say, 330 mm., the hyperfoci for stops 5.6, 8, 11, 16, 22, and 32 are respectively 59, 41.2, 30, 20.6, 15, and 10.3 m. The focusing scale has x for these distances equal to 1.8, 2.6, 3.6, 5.3, 7.3, and 10.5 mm., and these are the half-widths of the brackets. (A short cut for such a calculation is to combine the formulas

$$x = f^2/H \text{ and } H = 1{,}000\, f/S \text{ into}$$
$$x = f\,S/1{,}000\text{—all in mm.)}$$

In such a case the dimensions are large enough to make the scales true size.

In conclusion: The photographer can make many useful calculations with lens formulas derived from simple geometrical considerations. The most important of these calculations are performed almost automatically with the depth of focus scale. For cameras not originally equipped with such a device, one can readily design and construct one with the help of the lens formulas.

Book Reviews

MODERN PHYSICS

The Amazing Electron. James I. Shannon. xii + 248 pp. Illus. $4.00. Bruce Publ. Milwaukee. 1946.

THE scope of this book is much wider than indicated by its title. Not only does it give a detailed account of the discovery of the electron fifty years ago and of the study and application of this all-important fundamental particle, but it covers many related parts of the vast body of knowledge known as modern physics. In fact, in addition to ten chapters devoted more or less exclusively to the electron the book contains seven chapters with the following headings: Positive Rays, the Mass Spectrograph, Isotopes; X-Rays; Radioactivity, Alpha Rays; The Neutron, the Positron; Structure of the Nucleus, Artificial Disintegration of the Atom, Induced Radioactivity; The Nucleus—Resistant to Change Yet Occasionally Changing, Splitting; Cosmic Rays.

Intended for the general reader, the book carries the description and explanation of the remarkable new phenomena as far as is possible without the use of mathematics and extensive technical language. Nevertheless, the author has found it advisable to append a thirteen-page glossary! The exposition is clear and vivid throughout. The following paragraph will indicate the style and pedagogical skill of the author:

> We have all seen shooting stars. Or have we? The ordinary shooting star is a tiny body of a few grains in weight perhaps fifty miles above the earth. It is visible only by reason of the streamer of incandescent particles of its own substance which it trails across the night. So, too, the alpha particle becomes visible by the line of fog particles drawn around the ions which the alpha particle has created by its own energy and at the expense of its energy. If we claim that we see a shooting star we can claim that we see an alpha particle (pp. 122–123).

The book represents popular science writing at its best, and it is to be hoped that it will find many readers.

In spite of the care with which the book has evidently been written, it is not entirely free from errors. Thus, on page 3 the reader is given the impression that Planck is an experimental physicist, and on page 110 the common error is repeated that Bohr, in 1913, considered only circular electron orbits. The only error that may disturb the reader occurs on page 46, where it is stated that the electric field rather than the magnetic field is reversed in Thomson's positive-ray apparatus.

The emphasis is on the description of experimental facts and on their practical application. Though this is as proper as it is inevitable in view of the great difficulty of popularizing theoretical physics, it seems to the reviewer that the complete neglect of what may roughly be called the philosophical implications of modern physics constitutes an unfortunate limitation of the book. Neither Heisenberg's uncertainty principle nor Bohr's concept of complementarity are mentioned, although they are essential for the understanding of the atomic phenomena. The author discusses such matters as electron spin and the tunnel effect as if they could be understood on the basis of classical ideas, and he does not indicate to the reader that no casual space-time description can be given of electrons bound in atoms or molecules. The wave-particle duality is treated at some length without reference to the conceptual dilemma which troubled physicists for years,

nor to its removal by Bohr. It must be admitted, of course, that an adequate discussion of such matters cannot be given in a popular book. Nevertheless, if one regards ideas as well as things as important, one must regret that the author has made no attempt to indicate to his readers that the atomic phenomena have forced scientists to admit the limitations of their most basic concepts and to adopt strange new modes of thought.

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THEIR FAITH WAS EARLIER UP

Daniel Coit Gilman: Creator of the American Type of University. Abraham Flexner. ix + 173 pp. Illus. $2.00. Harcourt, Brace. New York. 1946.

Henry Sewall: Physiologist and Physician. Gerald B. Webb and Desmond Powell. ix + 191 pp. Illus. $2.75. Johns Hopkins. Baltimore. 1946.

Charles-Édouard Brown-Séquard: A Nineteenth Century Neurologist and Endocrinologist. J.M.D. Olmstead. 253 pp. Illus. $3.00. Johns Hopkins. Baltimore. 1946.

DOING the things already being done never interested Daniel Coit Gilman. As a youth, curiosity led him in many directions. For long he remained undecided in choosing a career. He found pleasure in the fine arts, learned business methods, and attended religious services: Catholic, Protestant, and Jewish. At Yale he excelled as a student. Later, at Harvard, he began the study of physical and political geography under Gayot. Then he went to Europe as attaché to the American Legation at St. Petersburg. There his future weighed heavily upon him.

He longed to influence New England minds (he was born in Connecticut); perhaps he might do best in the ministry. This idea he rejected; he would "want to preach about everyday affairs" and not upon "original sin and doctrine of election."

It "should not have been difficult to predict which of Gilman's competing interests —religion or education—would ultimately gain the upper hand." His task was set. It was to win adherents to the teaching of science, and to arouse the entire nation to an understanding of the importance of the "new educational gospel." How he proceeded to this end, the tools he fashioned, and the brilliant achievement, is the story Dr. Flexner has told with succinct and engaging simplicity.

Gilman knew perhaps better than any other man of his time the woeful lack of opportunities in America for those who wished to study science for its own sake. But he was no advocate of the ivory tower; he saw clearly the ultimate benefits pure science could bring to the industrial life of the nation.

In 1856 he prepared a plan for the complete organization of a school of science. He criticized elementary studies in the schools as "dull, repetitious, repellent." To this interest in the public schools he remained steadfast throughout his life. While President of The Johns Hopkins University he served as a member of the Baltimore School Board. Mencken remembers how at the very first meeting he "horned into" the minutest details, and how "within a couple of weeks he was the real boss of the whole school system."

In 1872 Gilman became President of the University of California. An environment "relatively free from hampering traditions" suited him. He did not know then, but later found out, that "the Board of Regents, while high-minded men, were without academic experience and were inclined to regard the teaching body as employees." Problems quickly arose; the faculty was in part "incompetent and unfit." In the eyes of the Board of Regents

Gilman was only another professor. He confessed himself anxious as to "whether the people of this coast are yet ready to pay for the luxury of such institutions." When the opportunity in Baltimore arose, he resigned. His "friends were saddened; his critics stunned."

In Baltimore Gilman had "no opposition to overcome, no vested interest to combat, no tradition to defy." Suddenly he had before him abundant resources, or so it seemed, and a clean slate. He knew precisely what he wanted to do, and did it.

Henry Sewall was to inherit the benefits of Gilman's genius. He joined Henry Newell Martin, a twenty-eight-year-old Irishman whom Gilman had selected for his first professor of biology.

Henry had been a sickly child; accordingly, his schooling had been desultory. His scholastic marks were good, but his demerits at times were excessive. At an early age he decided to become a doctor and was among the first to enter the scientific courses at Wesleyan when, as he put it, they were still "unjellied." Thus he slipped in. "The vague state of the scientific curriculum was wholly agreeable to Henry Sewall's disposition."

With many handicaps he arrived at Johns Hopkins. He lacked funds and health, and besides he also lacked stability. He was brilliant and intense, but he was likely to lose one idea in the excitement of the next. Martin, however, taught him a certain discipline of mind. The days were filled with happy excitement. In the air there was the "feeling of being present at the birth of great events." At any moment a whole new field of truth might be uncovered. Sewall watched and worked.

Like others of his time he became a traveling fellow and sought the great Carl Ludwig in Leipzig. In France, as in England, doctors were still being trained by the apprentice system dating back to the Middle Ages. In Germany things were different. Medicine had been conceived philosophically; it was a part of the university curriculum, offering medical students rigorous and broad education in the sciences basic to medicine. In England most students despised these sciences as "stinks." In France it was no better.

Sewall must have been deeply impressed by Ludwig.

> Here was the old man patiently plugging away after the fatigues of a busy day in order to clear up a new fact which would not wait for solution. . . .It set me to thinking, perhaps it was this sort of thing that made Ludwig pre-eminent.

Although he lived to be eighty-four, Sewall was never to reap the full harvest of his early enthusiasm. Ill-health followed him to the University of Michigan, where he became Professor of Physiology in 1882. But the "malaise of tubercle" was soon to overtake him. In Frederick Novy's first laboratory of bacteriology at Michigan, Sewall saw, among other things, the tubercle bacillus in his own sputum.

Intermittently he labored on. Perhaps his contributions to science were not great. Ill-health had brought a crisis in his life. His achievements may have had little influence on his scientific contemporaries, especially in Europe, but the fault was not his. Sewall proved the efficacy of immunization to snake venom, anticipating the discovery by von Behring of diphtheria antitoxin.

In 1891 Sewall took the long road to Denver to "hang out his shingle" at a time when "Colorado, creosote, and whisky" were considered to be cures for consumption, but never did he desert the study of disease.

The life of Charles-Édouard Brown-Séquard is the near tragedy of perpetual frustration. He was a thin little man with vivacious speech and hurried walk, and in his eyes was a nervous restlessness. When he wrote; "Despair and uncertainty, these are my lot," he was revealing his inner

self. His is a quixotic story of prophetic instinct and restless industry in one who frequently deluded himself by the very completeness of his theories. Perhaps, too, it was that he moved throughout most his life in the overpowering shadow cast by his brilliant and illustrious contemporary, the great experimental physiologist, Claude Bernard.

Moreover, Brown-Séquard was born to a feeling of insecurity, posthumously, on the island of Mauritius, which lies eastward of Madagascar. His mother was French and his father an American sea captain from Philadelphia. There were early struggles even for food and lodging. Then his mother died. He tried futilely to escape reality by periodic flights overseas. This impulse took him to America some sixty times, where there was a series of short-lived professorships, first at the College of Virginia and later at Harvard. But there was no peace in him. To eke out his resources he once taught French in New York and attended obstetrical cases at five dollars each. The idea of research in medicine had not yet entered the academic life in America.

Finally—and at long last—he won the coveted chair of medicine at the Collège de France. Bernard had died. But Brown-Séquard's best years had slipped away; he was sixty-one. In his zeal he became obsessed with a theory of epilepsy and the inheritance of acquired characters which only "cataclysmic evidence" could prove.

At the waning age of seventy-two, came the strange finish to fifty years of incessant investigation. Brown-Séquard became interested in rejuvenation. His organ extracts set the medical world in a furor, and his laboratory was swamped in their making.

The aging professor had lived beyond his time. At forty his fame as a physiologist was secure. He had shown the course of the sensory tracts of the spinal cord, the effects of sympathetic stimulation on blood vessels, and the necessity for the adrenal glands. But he must be ever searching, restlessly. Perhaps his mother years before had divined his burden: "He would like to know everything and understand everything at once."

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STATE OF OUR FORESTS

Problems and Progress of Forestry in the United States. Report of the Joint Committee on Forestry of the National Research Council and the Society of American Foresters. v + 112 pp. $1.75. Society of American Foresters. Washington. 1947.

THIS is more than a report on the state of our forests. It is a plan of action and a blueprint of a forest policy for the nation. The report is comprehensive in scope, yet at the same time specific and detailed in its application. It covers almost all the generally recognized forest problems. The discussion of each problem is accompanied by detailed recommendations. The report has been prepared by a committee of outstanding leaders in the profession under the chairmanship of Dean Henry S. Graves. There is no other forester in this country today who could bring to the discussion of forest problems greater experience and more objective, mature judgment.

The picture of the present forest situation which the report draws is not very rosy. The total area available for timber production is now only about 460 million acres. Of this only about 101 million acres are old-growth forest. Our reliance in the future, therefore, must be on second growth. Overcutting and fires have degraded these young stands to such a point that present production is inadequate to serve as a foundation for continued service of forests when the old-

growth timber that now serves the country is removed.

The crux of the entire report is the recommendation of the committee with regard to regulation of timber-cutting on private lands. This problem has plagued the forestry profession for the past 35 years. It is therefore significant that the committee, unanimously approved the principle of regulation of cutting on private lands as an essential step in preventing devastation of forest land. The committee recognizes the responsibility of states and their basic authority to prohibit practices impairing the forest. It recognizes also, however, the limitations of state regulation and comes out for Federal regulation in states which fail to undertake effective state regulation.

The best chapter, in my opinion, is on education and research in forestry. This discussion bears the imprint of Dean Graves's thinking; for a long time he preached the need of building a scientific base for the profession of forestry, of raising the level of forest education in basic sciences, and of developing scientific endeavor if forestry is not to lapse into a semivocational profession.

In this report the leaders of the profession spelled out clearly and authoritatively for all to read and ponder what the forest problems are and what are the measures needed to meet them in the postwar period.

RAPHAEL ZON

Washington, D. C.

ALL KNOWLEDGE

Science Since 1500. H. T. Pledge. 357 pp. Illus. $5.00. Philosophical Library. New York. 1947.

THE first impression made by this book is one of contrast between the size of the book and its scope as expressed by its title. How is it possible to cover the history of mathematics, physics, chemistry, and biology for four and a half modern centuries in a book less than one inch in thickness? The prospective reader must not be misled by this contrast into supposing that the book is a brief summary, suitable for popular reading; if he lacks scientific background he will find it rather difficult. The object and character of the book are well expressed in the following quotation from its preface:

> In view of the increasing number of manuals on the history of special scientific subjects published or projected by the Science Museum, it seemed desirable that a background study should be made. The present book, however, tries to fill a niche not only in the Museum series but in the rather small group of studies of the history of modern science as a whole which have been published anywhere, or at any time. The presence of this niche is soon explained. There now exists a considerable production of virtually professional work in the subject, in the midst of which Sarton's vast "Introduction" towers like a monument. But Sarton is still at work on the 14th century. For the modern period his present scale of treatment is clearly impossible. What is happening, instead, is that workers are clearing up obscure individual points; and by so doing are gradually, but in the end considerably, altering our view even of the well-known landmarks. There is thus a need, every decade or so, of short co-ordinating surveys. . . .Such surveys must of necessity grow more technical as time goes on. . . . The result is a book aimed primarily at. . . the scholarship candidate, the university student, the research worker.

The days are long past when a reviewer (like Lord Bacon) could take all knowledge for his province; and the comments of the present reviewer are to be considered as applying only to his own specialities—mathematics and physics. It is probably safe, however, to assume that the chapters dealing with chemistry and biology are similar in general character.

Histories of any subject are divisible into two classes—encyclopedic books of reference containing dates and events, important and unimportant; and treatises of a more philosophical character, pointing out lines of progress, and sequences of cause and effect, how earlier work gradually led up to later important results. The book under review belongs in the latter class. For instance, in the

concluding discussion in the final chapter, emphasis is laid on the relation of the growth of our knowledge to its material backgrounds, geographical and industrial; how after the Middle Ages science in Europe revived first in the commercial republics in Italy and then spread to the more northerly trade region of the Hanse. It was for long plainly governed by the needs of navigation, and migrated in the seventeenth century to commercial England and Holland. It became notably German and physicochemical with the rise of the chemical, electrical, and other German industries in the nineteenth century.

As to accuracy, the book seems excellent for a first edition. In the chapters on mathematics and physics, the reviewer has noticed only three errors, two of which are obviously typographical. On the whole, for the class of readers mentioned in the preface, the book can be recommended as excellent and mentally stimulating.

PAUL R. HEYL

Washington, D. C.

THE PROBLEM OF OUR TIMES

Can Science Save Us? George A. Lundberg. 122 pp. $1, paper; $1.75, cloth. Longmans, Green. New York. 1947.

THIS provocative little book by a well-known sociologist is based upon several articles which he wrote for *Harper's* and THE SCIENTIFIC MONTHLY. Most of these articles were written before August 1945, that is, before the atomic bomb. Perhaps this explains why so little of Dr. Lundberg's discussion is concerned with the gravest problem of our age, the threat of atomic warfare. Perhaps, too, this explains the absence throughout the book of the sense of urgency implied by the title.

The author's statement of the problem of our times is familiar to social scientists and might be summarized as follows: the great material progress achieved by man with the aid of the physical sciences has not solved problems of human relationships—depressions, strikes, wars. People have learned to think scientifically about natural phenomena but not about social phenomena. Why? Primarily, says the author, because of tradition and the failure of our educational system adequately to teach scientific method in the schools. The book is essentially a plea for scientific research in human relations. Only when the social sciences receive the same support as the physical sciences will mankind solve its fundamental social problems.

In Dr. Lundberg's laudable desire to sell the social sciences he has eliminated by definition all that is controversial and, I would add, all that is vital, in the social sciences. He views the social scientist primarily as a technician. His emphasis throughout is upon counting rather than thinking, upon the application of statistical methods rather than upon creative analysis and original hypothesis. For example, Dr. Lundberg thinks that the public opinion poll is one of the greatest achievements of modern social science, one "... which may rank in importance with gunpowder, telephone and radio" (p. 39)!

The social sciences, like the physical sciences, must be "non-moral;" they must deal only with means, never with ends, says the author. But how can one be "non-moral" in dealing with human beings, with human relationships? It seems that Lundberg's "non-moral" social scientist would also have to be immoral and unprincipled. For he suggests (p. 48) that social scientists must be ready to serve any political regime which happens to be in power. And, conversely, he says, "The services of *real* social scientists would be as indispensable to Fascists as to Communists and Democrats, just as are the services of the physicists and physicians" (p. 48). But isn't there a fundamental contradiction between totalitarianism and the kind of freedom necessary for honest social science?

Were the German anthropologists who preached Aryan superiority for the Nazi regime the "*real* social scientists"? Or were the real social scientists those who refused to distort the truth to suit the purposes of fascism? Dr. Lundberg labels as mere "cliché" the claim that science (including the social sciences) can flourish only in freedom. What contributions were made to the social sciences under nazism? Was it Hitler's guiding principle in human relations that the greater the lie the better? Was it the Nazi solution to the problem of minority groups by mass extermination? Or was it the development of some new polling technique?

When Lundberg leaves the more general theme of the social sciences and human relationships to deal with specific contemporary issues, he becomes cynical and academic and has little to offer except the inadequate slogan, "More research." Furthermore, he passes off his own personal (and perhaps political) convictions in the name of science, a practice which he eloquently denounces in others. He shows a condescension bordering on contempt in his treatment of "one-worlders," "idealists," and "internationalists" who "unscientifically" look to the United Nations Organization for peace. But then we learn that he favors Churchill's plan for a Western bloc (presumably against Russia), and he implies that this plan is more in line with the findings of social science, since regionalism is a necessary stage in the evolution from nationalism to internationalism (p. 108)! Does Dr. Lundberg really believe in the discredited stages theory of the unilinear evolutionists, or is it simply a convenience for his argument?

In his comments on war and peace he states categorically that wars can only disappear gradually and he suggests that we may be violating "natural processes" in trying to eliminate war before the time is ripe! This is a good example of preatomic-age thinking. How many atomic wars can we survive?

Can the social sciences save us? Perhaps. But, it seems to me, only if social scientists become as much concerned with where we are going as with how to get there. If it is a question of salvation they can be more effective as intelligent and moral citizens than as "non-moral," robot-like technicians.

Oscar Lewis

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BIRDLORE

Life Histories of North American Jays, Crows and Titmice. Arthur Cleveland Bent. xi + 494 pp. $1.75. Government Printing Office. Washington. 1947.

Mr. Bent has brought together the observations of several hundred bird enthusiasts—including his own—and woven these observations into a very acceptable whole. He may have reduced objectivity, but he has certainly added interest by frequent direct quotations from contributors. George B. Simpson, for example, not only tells something about the Oregon jay, but also about himself when he says, "Unlike some of our race they [Oregon jays] have a passion for soap." W. M. Tyler describes the blue jay and at the same time tells how he feels about him: "The blue jay is a strong, healthy looking bird, noisy and boisterous. He gives us the impression of being independent, lawless, haughty, even impudent, with disregard for his neighbors' rights and wishes—like Hotspur, as we meet him in Henry IV, part 1." Bradford Torrey (1885), as quoted by W. M. Tyler, gives his impression of a pair of chickadees in the process of nest building:

> Their demeanor toward each other all this time was beautiful to see; no diffusive display of affection, but every appearance of mutual understanding and

contentment. And their treatment of me was no less appropriate and delightful,—a happy combination of freedom and dignified reserve.

Thirty-four jays, four ravens, eight crows (including two species of magpies), the Pinyon jay, Clark's nutcracker, and thirty-nine titmice are discussed. The author has attempted to "give as full a life history as possible of the best known subspecies of each species and to avoid duplication by writing briefly of the others and giving only the characters of the subspecies, its range and any habits peculiar to it." Depending upon the information available, he divides the discussion of each species or subspecies into the following categories: habits, nesting, eggs, young, plumages (with emphasis on the young and differentiating characters among subspecies), food, behavior, voice, field marks, enemies, courtship, migration, egg dates, and distribution. Adding much to the book are sixty-eight plates. A useful bibliography of some 275 titles is included. The index covers authors and species. This is fifteenth of the series on life histories of North American birds.

Full of colorful and enthusiastic, as well as accurate and detailed, description, this book makes pleasant and informative reading. Even side lights on some common names are given. The author points out that the name "whiskey Jack," signifying the Canada jay, did not grow out of any fondness for hard liquor on the part of the bird—though he seems to be fond enough of any other supplies the camper might have. Instead, it is a corruption of the old Indian name *Wiss-ka-chon*, first to "whiskey John" and then to "whiskey Jack."

A. O. Gross, in his excellent section on the Eastern crow, says that contrary to what we might expect (in view of the crow's lack of proficiency in singing) the tracheal syrinx and its controlling muscles are well developed; hence, the ability to learn to say "papa," "mamma," and other simple words as well as effectively to imitate human laughter. Gross cites work of Charles A. Coburn which demonstrated that crows could with very little practice distinguish between a circle, a triangle, a square, and a hexagon. This "convinced" Coburn that "Henry Ward Beecher was correct when he said that if men could be feathered and provided with wings very few would be as clever as crows."

The discussions of food taken by birds are particularly valuable. Gross, commenting on the crow, says: "Its food varies so greatly that isolated observations may be misleading unless the food habits are considered from the standpoint of the entire population through all the seasons of the year." W. L. McAtee, according to W. M. Tyler, has shown that seven-tenths of the chickadee's food is of animal origin. It includes such forest pests as the flat- and roundheaded wood borers, leaf beetles, white pine beetles, tree hoppers, coddling, gypsy, and browntail moths, and many others.

Throughout, the ecological relationships are well demonstrated—especially as between man and the birds. In many cases, notably with the crow and magpie, man has by the nature of his food-producing ability and his need and ability to protect his production, assumed the contradictory roles of best friend and worst enemy. These contradictions can only be resolved by further thorough and continuous study. Then, and only then, can we intelligently decide if "artificial" control is necessary, and, if so, what it shall be.

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Comments and Criticisms

THE NATURE OF LIFE

Thomson King's thoughtful essay on the nature of life as an unknown essence shows that our present knowledge of the subject is in much the same development stage as that of heat at the time when it could be defined as a substance called Phlogistin. That we now know the nature of heat fairly well does not assure by analogy, however, that we will ultimately know the true nature of life. In trying to study the ultimate nature of matter, we arrive at the Heisenberg uncertainty principle which shows the limit of our ability to gather factual evidence, beyond which point we can only infer. Similarly, when we attempt to define the exact nature of life, it is quite possible that we will run into a barrier of complexity. In Gerard's SM article of June 1946 the limitations of our imagination are admirably expressed. It may well be that the processes of cycles and configurations of matter which make up the most elementary life units are so complex that even with advanced training we shall be unable to set up imagination patterns which will correspond to the actual picture of life, at least in our stage of evolution.

For one point of issue as to the origin of life, King does not believe that life could have commenced by chance combination in the early oceans. As evidence is cited the fact that we can and do duplicate similar, or possibly more favorable, mediums in the laboratory and yet cannot synthesize life. The evident complexity of an elementary life unit makes the improbability of a chance combination of such a unit nearly infinite, and yet the possibility of the event occurring was nearly infinite in the vastness of the ancient seas and of the countless centuries. To attempt even a 50-50 chance of repeating the event, a scientist would have to construct a laboratory just as big as the seas and would have to wait just as long. He would have no other recourse. Not knowing what he was trying to build, he could set up the exact train of operations to produce the event in the confines of a small laboratory only with an infinity of tries.

Assuming the event actually occurred on earth, it could have been stopped at the time only by another chance combination, equally improbable as the one that started it. After the first cycle and multiplication, the possibility of stopping life on earth became successively less with each multiplication as long as the original surrounding conditions prevailed. Shrödinger has shown how the life genes could mutate naturally by statistically occurring concentrations of energy and, as we know from the history of evolution, with frequent probability. These mutations have provided life with a possible means for continuance even when surrounding conditions changed.

PHILIP EWALD

Sheffield, Ala.

IDENTIFICATIONS

Thank you for your explanation of the doubtful identities in William Newberry's poem ["Beyond Time and Space," February SM, p. 108]. With this help, I can see why they did not coincide with my ideas: Mr. Newberry is judging his individuals by their *impact* upon human thought, not by their extensions of logical thought and strict adherence to the scientific method, as I was.

Kant and Marx were undoubtedly magnificent thinkers, but was it *scientific* thought? Scientific procedure requires that conclusions must follow mathematically, i.e., with rigid logic, from the general theory, and check with experiential realities. Kant and Marx certainly "pursued the quest of knowledge," but their methods and results, in my opinion, have cemented another tier upon "the barriers than can immure the groping thoughts of man." Marx and his avowed followers have definitely budged the world (in a manner not as permanent as Einstein's, I hope!), but can we ascribe the influence of studies of this type to their logical content, or rather to their similarity to works in the field headed by Christ, Buddha, and Mahomet? How much the gain to substitute both Kant and Marx with Pareto, and stick with pure science!

Perhaps Mr. Newberry was unfamiliar with Georg Cantor's *Begründung der transfiniten Mengenlehre*, which first "encompassed all infinity;" otherwise I am sure he would have seen how much better the phrase fitted Cantor than Einstein.

CHARLES T. HOARD

Seattle, Wash.

The individuals characterized by Mr. Newberry were: Newton, Mendel, Kant, Einstein, and Marx, in that order.—Ed.

ORTHODONTIA

C. Judson Herrick's article, "Seeing and Believing," in the March SCIENTIFIC MONTHLY interested me. Particularly did his account of his illusion that the night boat was moving the wrong way on the Ohio River rouse old memories.

I used to travel 100 miles to Norfolk every two weeks to get my teeth straightened, and on every trip I would entertain myself by reversing the apparent motion of the train. This I found I could do quite easily by simply—in my mind—throwing a lasso around the telephone pole and pulling the train in the other direction.

I still have this power and still use it.

JOHN WHITE

Times Herald
Washington, D.C.

JEREMIAH DIXON?

Jeremiah Dixon (There were several of him in 1773).

H. W. Robinson, Esq., Librarian of the Royal Society, has kindly pointed out a misstatement in my article "Charles Mason and Jeremiah Dixon" published in *The Scientific Monthly* of June 1946. I said: "Jeremiah Dixon was made a fellow of the Royal Society on November 18, 1773."

This statement is true of one Jeremiah Dixon but not of the Jeremiah of Mason and Dixon. Mr. Robinson has supplied the following about the Jeremiah Dixon of whom my statement is true.

JEREMIAH DIXON (1726–1782)

Jeremiah Dixon was born in the year 1726. He was the son of John Dixon of Leeds, Merchant, and Frances, daughter of Thomas Glover. He married Mary, daughter of the Reverend Henry Wickham, and had a family of three sons and four daughters. He carried on the family business in Leeds as a merchant, and resided at the ancestral home of the family at Gledhow Hall, near Leeds. He was elected a Fellow of the Royal Society on 18 November 1773. Armiger. High Sheriff of the County of York. Died 7 June 1782, aged 56. Buried at Leeds. One of his sons, also named Jeremiah (b. 1753) married Mary, daughter of John Smeaton, the builder of the Eddystone Lighthouse.

Most of the above information is taken from the authenticated pedigree of Dixon of Heaton Royds—Foster, J. *Pedigrees of County Families of Yorkshire, Vol. 1.*

His certificate of election to the Royal Society reads as follows:

Jeremiah Dixon, Esq. of Gledhow near Leeds, Yorkshire. A gentlemen of great worth and merit, well acquainted with, and a lover of Philosophical Enquiries; being desirous of becoming a Fellow of the Royal Society, we whose names are hereto subscribed do on our personal knowledge of him recommend him as likely to become an useful and valuable member, and as truly worthy of that honour.

(signed) J. Smeaton
Geo. Savile
Benj. Wilson
John Caverhill
Joseph Priestlay
S. Harper

THOMAS D. COPE

Randal Morgan Laboratory of Physics
University of Pennsylvania

A SAD ADMISSION

In days of old, so I am told,
The scientists were strong and bold,
And neither priest nor mighty prince
Could dim their erudition.

Tycho, Kepler, Galileo,
There you had a fearless trio
Who were not afraid of Leo
's inquisition.

But today, ah sad admission,
He who yearns to study fission
Kneels and begs a politician
For permission.

And if the seedy politician,
Who is head of some commission,
Does not favor the petition,
There's no fission.

M. KESSLER

Duke University

Technological Notes

Releases and miscellaneous publications that reach the editor's desk afford many side lights on the scientific scene, particularly in bringing out ingenious applications of principles. Sometimes they suggest subjects for articles. Occasionally they bring to our attention some device that will be useful around the home or laboratory. So we have asked a friend to write these notes as a sort of review of releases and related topics.—Ed.

Avocados by Air. An editorial in *Technology Review* brings out the use of airplanes in the modern practice of rushing food to market. In 1946 about a million pounds of avocados, one-fifth of Cuba's crop, were air-shipped to the United States. Bananas, too, come by plane as well as by banana boat. Fruit that has ripened on the plant is often so much better than that picked green for long shipment that the purchaser is willing to pay the extra price. Besides, there's the saving of ripening cost and spoilage.

Not so Modern. Market facilities, a Department of Agriculture release reminds us, are in many ways about as modern as mustache cups. They include weather-beaten shelters along country sidings, and smelly metropolitan terminals. Of twenty markets studied, only five were "fairly modern," and in fifteen traffic congestion caused expense, waste of time, and deterioration of produce.

Dodder. The parasitic plant called dodder twines around its victims and sucks the sap out of them. That objectionable property has been turned to good account in study of the spread of curly top, a virus disease affecting sugar beets and other Western crops. The virus is spread by the beet leafhopper. In research on the disease, hairy-leafed plants like tomatoes and tobacco gave trouble because the hoppers do not feed readily on the hairy leaves. Dodder grown on infected plants was a laboratory aid; it absorbed the virus along with the sap, and the hoppers sucked infection from the smooth dodder stems.

Should We Take the Money? China, which certainly needs what foreign exchange she can lay her hands on to buy practically everything we make and raise, has resumed the purchase of American ginseng, the National Geographic Society tells us. That profitable trade amounted to more than a million dollars in 1940, although no therapeutic value has been found in the withered root.

Beavers. Summer travelers in northern Minnesota can observe the beaver, cherished for his pelt and interesting housing habits. They can also check a complaint, recently carried by *American Forests*, that increase in the number of beavers and beaver dams has not been an unmixed blessing. Drowned-out forests are reported, and highways broken by treacherous ditches. Open season on the busy creatures is commended.

Useful Odors. Some graduate students at Ohio State once played a mean trick on their landlady; over her door they hung a sign with the elegant name "Mercaptan Manor." The bad odor of mercaptans, Dr. C. M. Suter of the Sterling-Winthrop Research Institute, Rensselaer, N. Y., told the Northeastern Section of the American Chemical Society, is used to good advantage; a whiff of it added to gas makes a small leak immediately evident. One of the mercaptans is BAL, the British antidote for Lewisite, fortunately not needed during the war. BAL has a peacetime future as an antidote for arsenic poisoning and perhaps for mercury poisoning as well.—M. W.

The Brownstone Tower

FROM its beginning the SM has been an illustrated magazine, publishing both half tones and line drawings, but it has never been a picture magazine, and the majority of its articles are still unillustrated. Though we hope that the SM will continue to have a greater appeal to the mind than to the eye, the average quality of the illustrations that we do publish can and should be improved. The SM does not enjoy the services of a staff photographer or artist or draughtsman; consequently we are dependent on contributors to supply suitable illustrations. Photographs are sometimes defective in clarity or composition, line drawings may be inartistic, and lettering on graphs may be irregular or too small. Such defects are not surprising in illustrations prepared by scientists who have not given special attention to photography and the graphic arts. Many scientists, however, are skilled in photography and should be able and willing to help those who, like the editor, have never advanced beyond the use of a box camera. And the help of artists and draughtsmen is available in most institutions. We hope that every contributor to the SM will consider the possibility of illustrating his article and will do his best to prepare or obtain illustrations that will be a credit to him as well as to the SM.

For those who are already interested in photography we are publishing in this issue an article by H. H. Bliss, who explains how a "photographer can make many useful calculations with lens formulas derived from simple geometrical considerations." When Mr. Bliss photographs a landscape, he evidently knows exactly what he is doing. We guess that rule-of-thumb photographers will be enlightened by his article.

In order further to encourage submission of better photographs for publication in the SM, the Publications Committee has recommended and the Executive Committee has approved the immediate initiation of a photographic competition, the details of which have been worked out by Mr. T. J. Christensen. Although we are interested in artistic photographs, we thought it advisable to limit the competition to photography as a tool of science. Photographs that serve as the data of scientific investigations are particularly desired, and those that have enabled scientists to learn something that could not be known or measured in any other way will receive special attention. For example, I am reminded of photomicrographs made some years ago by J. G. Pratt, then the photographer of the Bureau of Entomology and Plant Quarantine. He whitewashed and photographed the genetalia of species of ***Phyllophaga*** (beetles whose larvae are called white grubs) and thus aided in their identification.

I call the attention of our readers to the conditions and rules of our photographic competition which appear on the back cover of this issue. Dr. Alexander Wetmore, Secretary of the Smithsonian Institution, has reserved space in the Graphic Arts section of the Smithsonian Institution Building for exhibition of the selected prints from November 1 to November 30. They will then be sent to Chicago for showing at the scientific exhibition in connection with the A. A. A. S. meeting, December 26–31, 1947. Finally, the prize-winning prints will be published in the SM early in 1948, together with, we hope, accounts of the investigations in which the prints played a part.

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